NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

THESIS

**INTERNETWORKING:
PLANNING AND IMPLEMENTING A
WIDE-AREA NETWORK (WAN)
FOR K-12 SCHOOLS**

by

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September 1995

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This thesis documents the planning, design and implementation of a regional wide-area network connecting K-12 schools, research institutions, libraries and institutions of higher education throughout the Monterey Bay area of California's central coast. The goal of the network is to enable students and educators to have access to the environmental information and resources available regionally via the Internet, at speeds which will encourage interaction and maintain interest. The wide-area network design process presents numerous human and technical challenges. These challenges are further amplified by the need to enable educators to design and implement school local area networks concurrent with the wide-area network solution. The processes used to resolve these myriad issues and the resulting solutions are of direct relevance to the K-12 community as well as network planners, administrators and funding partners.

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INTERNETWORKING: PLANNING AND IMPLEMENTING A WIDE-AREA NETWORK (WAN) FOR K-12 SCHOOLS

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ABSTRACT

This thesis documents the planning, design and implementation of a regional wide-area network connecting K-12 schools, research institutions, libraries and institutions of higher education throughout the Monterey Bay area of California's central coast. The goal of the network is to enable students and educators to have access to the environmental information and resources available regionally via the Internet, at speeds which will encourage interaction and maintain interest. The wide-area network design process presents numerous human and technical challenges. These challenges are further amplified by the need to enable educators to design and implement school local area networks concurrent with the wide-area network solution. The processes used to resolve these myriad issues and the resulting solutions are of direct relevance to the K-12 community as well as network planners, administrators and funding partners.

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The author would like to gratefully acknowledge the patience, support and inspiration of Dr. Donald P. Brutzman and Rex Buddenberg. The author would also like to thank Dr. Nancy Giberson, Kam Matray, and Birt Johnson for their assistance in reviewing the document. This thesis is the culmination of a shared vision which became Monterey BayNet. Thank you to all of the many players who volunteered to help shape the future of education in the Monterey Bay region.

I. INTRODUCTION

As a member of the Initiative for Information Infrastructure and Linkage Applications (I^3LA) network design team this author participated in the design and implementation of a regional network, Monterey BayNet. The network connects kindergarten through twelfth grade (K-12) students, educators and research institutions throughout Monterey and Santa Cruz counties on the central California coast. Internetworking local area networks (LANs) over such a widely dispersed geographical area creates a Wide-Area Network (WAN) and presents many technical and human challenges. Lessons learned in solving these challenges are presented here to assist further expansion of Monterey BayNet, assist other K-12 schools and assist other individual groups building local and regional networks.

The importance and value of documenting such efforts can not be overemphasized.

> The technical issues associated with developing and deploying a national information infrastructure are far from resolved.... To a large extent, the National Information Infrastructure [NII] will be a transformation and extension of today's computing and communications infrastructure (including, for example, the Internet, telephone, cable, cellular, data, and broadcast networks). Trends in each of these component areas are already bringing about a next-generation information infrastructure. Yet the outcome of these trends is far from certain; the nature of the National Information Infrastructure that will develop is malleable. Choices will be made in industry and government, beginning with investments in the underlying physical infrastructure. Those choices will affect and be affected by many institutions and segments of society. [NRC, 94]

This case study is presented as a blueprint of Monterey BayNet design and implementation efforts. It is primarily written for the K-12 technology mentors who are interested in joining or creating their own regional network. Lessons learned are also applicable to creating community networks and internetworking Naval Bases. This work is particularly valuable as an example of the success that can be achieved through the collaborative partnership of the educational community, research community, commerce, and government.

A. BACKGROUND

In early 1994 a number of grants were funded that had been collaboratively planned to enable several independent organizations and volunteer groups to design and implement a regional wide area network (WAN) called Monterey BayNet. The initial Monterey Bay Regional Education Futures (MB ReEF) consortium design effort focused on the educational community, keeping a longer range vision of expansion to include partnership with commerce, tourism, and agriculture. A three-tier approach was adopted to match a hierarchy of service needs, expertise, and technology. Figure 1.1 shows the initial Monterey BayNet member sites as identified by the MB ReEF consortia for CalREN grant funding.

CalREN was created by Pacific Bell (PacBell) in 1993 to fund collaborative projects whose applications might revolutionize the ways that individuals and organizations communicate and share information [PacBell, 94]. Projects are focused in the Education, Health Care, Community, Government, and Commercial Business areas. Projects are funded for a maximum of two years and connect using PacBell data communications technologies. Technologies available include Integrated Services Digital Network (ISDN), Switched Digital Service-56 (SDS-56), Switched Multimegabit Data Service (SMDS), Frame Relay and Asynchronous Transfer Mode (ATM) [PacBell, 95].

The CalREN grant "*Destination Tomorrow: making connections for the ultimate field trip...*" requested funding for Pacific Bell telecommunications service to connect 43 regional test-bed sites [Matray, 94]. The grant was awarded 14 April 1994. Service installation fees and connectivity are fully funded by the CalREN grant until June 30th, 1996. Of particular interest in the awarding of this grant is that PacBell had not previously planned to deploy Frame Relay service in the Monterey Bay area as early as needed by the grant recipients. The collaborative strength and technical depth of the MB ReEF effort persuaded PacBell to advance scheduled technology deployment plans in support of the consortium and the community.

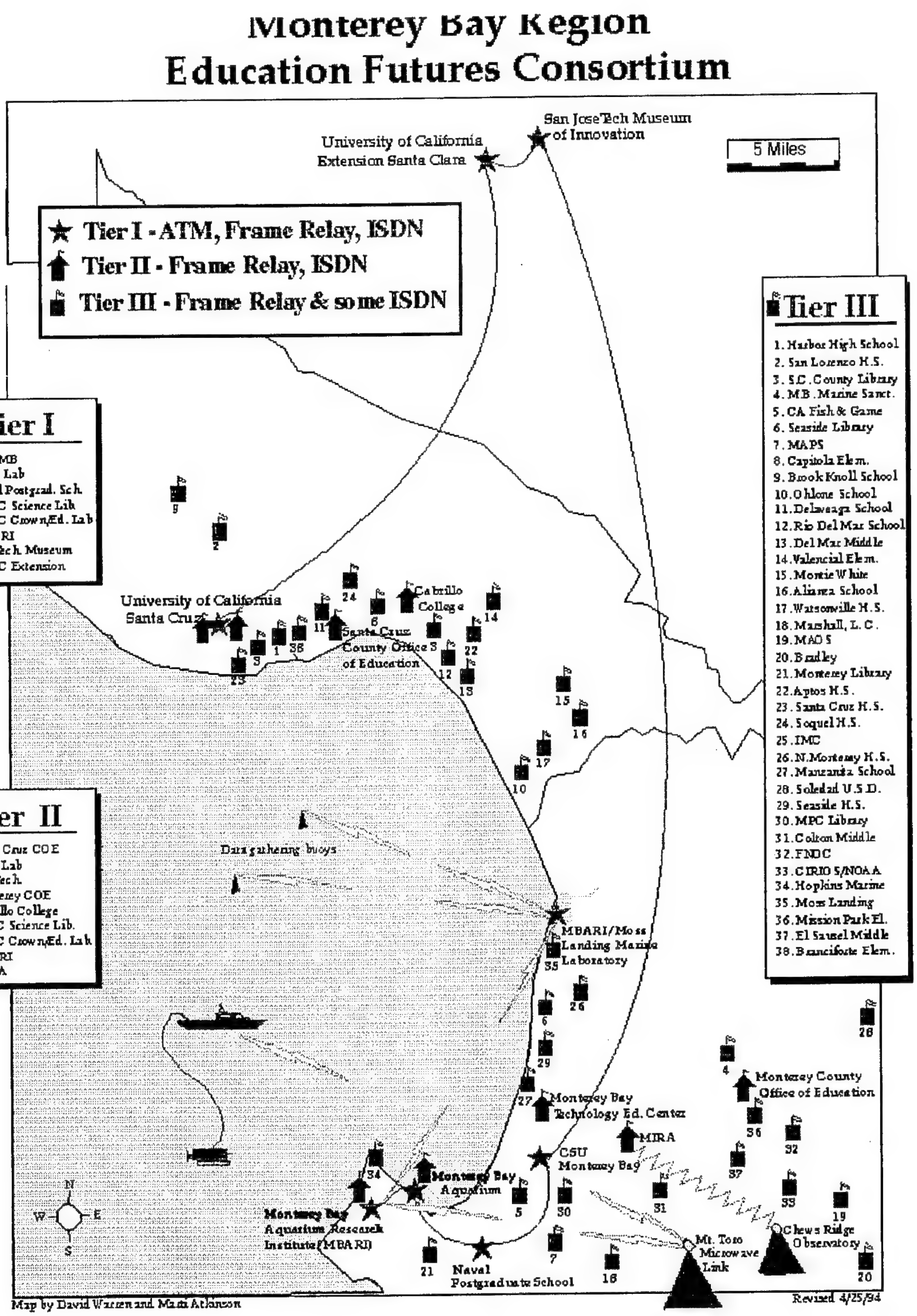


Figure 1.1 Monterey BayNet members.

The ATM backbone pictured in Figure 1.1 is deployed independently of the regional Frame Relay WAN topology. Discussion of ATM technology will be limited to overview material for comparison with the Frame Relay technology that forms the core of Monterey BayNet. Integrated Services Digital Network (ISDN) connections will someday be implemented in Monterey BayNet where studio quality videoconferencing is required. A comparison of ISDN and Frame Relay technology follows which explains the decision of the I^{3}LA network design team to choose Frame Relay over ISDN as the initial core technology.

B. MOTIVATION

Monterey BayNet is the child of several unique parents. The Monterey Bay Futures Network was formed by community leaders in response to the pending closure of Fort Ord. This group was interested in leveraging the regions unique environment-related resources with advanced information technology. The I^{3}LA consortium was formed bringing together researchers, government, and business for the purpose creating a sustainable regional information infrastructure. Members of the consortia include Monterey Bay Aquarium Research Institute (MBARI), University of California Santa Cruz (UCSC), California State University Monterey Bay (CSUMB), Naval Postgraduate School (NPS), Cabrillo College, Pacific Bell (PacBell), Lloyd Internetworking, Monterey County Office of Education (MCOE), Santa Cruz County Office of Education (SCCOE), Monterey Peninsula Unified School District (MPUSD) and others [Born, 95].

The network was envisioned as a community resource that might provide full access to the Internet via videoconferencing and hypermedia applications at a variety of bandwidth rates. The end goal is the creation of a "collaborative educational infrastructure around the Monterey Bay Sanctuary that will build a sustainable base and national model for the application of telecommunications technology in environmental education". [Matray, 94] "Life-long learning" and "access to informational and instructional resources" are the end products of Monterey BayNet, *not technology per se*

[Matray, 94]. Critical to the understanding of this project is that the technology is the vehicle for progress, not the end result. This thesis describes the development of that vehicle, which hopefully will enable the shared understanding of the region's resources.

> Three overarching and interactive elements will guide the development process within this *seasphere of influence:* high-speed data communications access and computer technologies are made available to K-14, scientific research communities, and libraries by business and industry partners. Based upon this access, educators, scientists, engineers, and technicians can work collaboratively to sort and identify relevant electronic data sources based on real world applications and real world interactions. [Matray, 94]

Technical problems have technical solutions. The truly difficult task within the consortia lies with those who are developing the regional content. The content is the final product which Monterey BayNet seeks to access. In this light the consortia quickly recognized that solutions to human issues, as well as technical ones, were critical to the long term success of the network [I³LA, 94].

This problem looks just like one facing Naval Bases all around the world today. Local and regional data sources desire the ability to share data. The Internet model provides an effective low-cost solution which can be adapted to meet the needs of a Naval Depot, Naval Air Station or Naval Base.

C. HOW TO USE THIS THESIS

This thesis follows the network design team's decision points and solution rationale in a logical order, rather than in a chronological order. It is tailored for the non-technical reader, so many technical details are (necessarily) presented in overview. It is intended to serve as an exemplar for similar networking efforts. Recommendations on how to use this thesis for different individuals follow.

1. Teachers and Students

Teachers and students can use this thesis to better understand the technology behind the Internet. This thesis can be used to design further expansion of existing networks, or to design and deploy entirely new local and wide area networks. Teachers entering the information era can begin to develop an appreciation of the magnitude of Internet resources and how to manage them in the educational environment. The document also provides guidance in troubleshooting and managing a K-12 LAN.

2. Policy Makers

Security, acceptable use, liability, life-cycle management costs and standardization are all key issues which were faced in implementing Monterey BayNet. This thesis can be used to demonstrate the need for policy, and to derive a starting point for policy formulation. Issues faced in the development of a K-12 WAN are present across all networked communities.

3. Network Builders

As with every project of any scale, some decisions were made which proved faulty. This thesis attempts to document them by containing a great many lessons learned. It can also be used to demonstrate the need for building a scalable infrastructure that supports future expansion through a range of user requirements. The document also can be used to compare the major strengths and weaknesses of emerging fast packet technologies such as Frame Relay, Integrated Services Digital Network (ISDN) and Switched Multimegabit Data Service (SMDS).

4. Network Administrators

This thesis clearly demonstrates the need for early investment in trained administrators and network management. This thesis is of particular value to administrators who are building a new WAN. This thesis can be used to highlight why there needs to be early and equal emphasis placed on network management and administration. This thesis demonstrates this need clearly by documenting the default management case. Further study of these topics will appear in *Wide-Area Network (WAN) Management: A Case Study* [Trepanier, 95].

5. Navy Personnel

This thesis can be used as a low-cost model for LAN and WAN connectivity in the Navy. It clearly demonstrates that information infrastructure installation does not require outsourcing for technical proficiency reasons. Individual commanders can perform most or all work required to connect to the Internet. This thesis can also be used to identify existing hardware which can be reused to lower installation costs. In today's environment of reduced budgets and transition toward commercial off-the-shelf (COTS) solutions, this project can be used as an exemplar. The issues involved at every level of design of this K-12 network have parallels within network design at DoD.

D. SUMMARY

Monterey BayNet is a regional WAN designed and constructed by a unique collaborative volunteer effort. Monterey BayNet is focused on the K-12 community, linking educators, students and researchers to the Internet with PacBell Frame Relay service. This thesis presents the major design and implementation issues faced by the network design team. This thesis was written primarily for the K-12 educator but parallels issues faced in every WAN environment.

II. RELATED WORK

The scope of Monterey BayNet project is well beyond the bounds of any single thesis. An overview of this diverse research effort appears in "Networked Ocean Science Research and Education, Monterey Bay California" [Brutzman, 95], emphasizing connectivity, content, access, and applications. Many of the issues which are covered in this thesis will require re-examination as technology advances and user needs evolve. Other related efforts complement and overlap this thesis. They include:

- *Realizing the Information Future: The Internet and Beyond* [NRC, 94] - Report of the National Research Council (NRC) NRENAISSANCE Committee. A critical examination of architectural and deployment issues relating to the creation of a National Information Infrastructure (NII). This report describes past and recommended future government involvement with the 'superhighway' initiatives forming the NII.

- *I^{3}LA Net Design White Paper* [I^{3}LA, 94] - The white paper is the initial focal document behind several Monterey Bay region initiatives. It provides necessary background information on the development of the I^{3}LA, its mission and goals. Included are an executive summary, profiles of member institutions, tiger team profiles, publicly accessible information resources and team member contact information.

- *Building the Future: K-12 Network Technology Planning Guide* - The California Department of Education's statewide networking standards [CDE, 94]. This document was carefully designed to provide broad guidance to K-12 institutions in the deployment of information technology. The guide clearly defines the need for Internet access throughout the K-12 community and the educational benefits that access will yield to teachers, students and society.

- *The I^3LA Network: Physical Configuration Team Project* [Trepanier et al., 95] - A report created by a team of Naval Postgraduate School students which describe the efforts of a Tier I Monterey BayNet site in technology transfer to Tier II and III sites. The team's effort is particularly successful in the area of equipment configuration and end-user training.

- *Using the Multicast Backbone (MBone) for Distance Learning: A Case Study* A master's thesis that documents the viability and impact of distance learning using the MBone [Emswiler, 95]. The case study documents the learning points derived from the successful world-wide multicast of the Dr. Richard Hamming course "Learning to Learn." The research provided complete course coverage, world-wide, for a full academic quarter. This is the first documented attempt of extending traditional education methods using the MBone.

- *Wide-Area Network (WAN) Management: A Case Study* - A master's thesis documenting the need and design requirements for a Monterey BayNet Network Information Center (NIC) and Network Operations Center (NOC) [Trepanier, 95]. *Wide-Area Network (WAN) Management: A Case Study* will provide a logical extension from this thesis, recommending solutions to problem areas identified in Monterey BayNet administration and management.

Numerous additional books and on-line resources exist for connecting to the Internet. Notable entries include:

- *Entering the World-Wide Web (WWW): A Guide to Cyberspace* [Hughes, 94].
- *The Web Empowerment Book* [Abraham, 94].
- *WWW Unleashed* [December, 95].
- *The Whole Internet* [Krol, 93].
- *World Link An Internet Guide for Educators, Parents, and Students* [Joseph, 95].

The Internet Engineering Task Force (IETF) is a volunteer group that "provides a forum for working groups to coordinate technical developments of new protocols. Its most important function is "the development and selection of standards within the Internet protocol suite." [Malkin, 94] A component of the IETF is the Internet School Networking (ISN) working group. The ISN was chartered to "address issues related to the connection of primary and secondary schools worldwide to the Internet." [Sellers, 95] The group maintains a general discussion mailing list isn-wg@nasa.gov. To subscribe to the mailing list send e-mail to listmanager@nasa.gov with the message *subscribe isn-wg* in the body of the message, leave the subject line blank. The group has issued several IETF Request For Comments (RFC) pertaining directly to K-12 Internet connectivity. They include:

- RFC 1578 *FYI on Questions and Answers: Answers to Commonly Asked 'Primary and Secondary School Internet User' Questions* [Sellers, 94].
- RFC 1709 *K-12 Internetworking Guidelines* [Gargano, 94].
- RFC 1746 *Ways to Define User Expectations* [Manning, 94].

On-line information pertaining to the Monterey BayNet effort can be found at the following Universal Resource Locators (URL):

- The I^3LA home page provides access to I^3LA summary information, proposals and anonymous ftp server. In addition it has many useful links to information sources on commerce, digital libraries, education, environment, government, National Information Infrastructure (NII), networking and telecommunications. Available at *ftp://taurus.cs.nps.navy.mil/pub/i3la/i3la.html.*
- The Learning About Monterey Bay (LAMBAY) home page provides information about the collaborative education and research surrounding Monterey Bay. Particular emphasis is placed upon the region's diverse habitats, including the unusual

marine life of the deep sea canyon [Atkinson, 95]. Links are provided to local education, research, libraries, and government sites. Available at *http://lambay.cse.ucsc.edu/mb*.

- The Monterey Bay Regional Education Futures (MBReEF) Consortium home page provides links to information sources throughout the Monterey Bay region. Included are links referenced by region, environment, education, research, libraries, government, commerce, tourism and culture. Available at *http://www.ucsc.edu/mbay-region*.

- The Real-time Environmental Information Network & Analysis System (REINAS) home page provides access to both real-time and retrospective regional scale environmental science via the REINAS distributed database environment. The REINAS project is a cooperative effort of Monterey Bay region meteorological and oceanographic scientists from the Baskin Center of the University of California Santa Cruz (UCSC), Naval Postgraduate School (NPS), Monterey Bay Aquarium Research Institute (MBARI), and the National Oceanic and Atmospheric Administration Center for Ocean Analysis and Prediction (NOAA/COAP). The REINAS Project is funded by the Office of Naval Research under a University of California Santa Cruz Research Initiative [Rosen, 95]. Available at *http://csl.cse.ucsc.edu/reinas.html*.

The amount of literature related to Monterey BayNet is considerable. The Monterey Bay region hosts numerous research initiatives, all of which will utilize Monterey BayNet as a vehicle for regional information dissemination. From the K-12 student perspective Monterey BayNet is the access mechanism which unlocks regional and global content. The references listed in this section provide a generous set of starting points for understanding the magnitude and scope of the interrelated Monterey BayNet projects.

III. PROBLEM STATEMENT

The fundamental problem examined in this thesis is how to cost-effectively and fully connect educators, students and researchers to the Internet. More specifically, since a predefined group of participants and technologies exist, the problem is "how do you cost- effectively connect the 43 Monterey BayNet sites using PacBell offered services"?

In each case the term cost-effective was used as a precondition to the required connection solution. This should be further clarified to reflect the financial constraints placed upon the client sites. Educational funding in California schools is such that every effort to save financial resources, without affecting upward scalability, must be exercised. The final solution must be the lowest cost solution which meets end user needs. California funding for technology in education was $2.35 per student in 1993, compared to $153.20 per student in Connecticut [Cradler, 1994] . In 1994 California was ranked last among states in a survey of student-to-computer ratios [QED, 94].

"What are the end user needs?" The primary end user in Monterey BayNet is the K-12 teacher or student. A method of determining what the end user expects from an information system is required in order to meet those expectations. This problem is compounded by the fact that present technology implementation in the Monterey Bay region's education system is so badly out of date. End users cannot be expected to accurately express needs without some knowledge of available systems. A baseline set of end user requirements must be established using available data that can later be evaluated and updated.

The main question is how to facilitate technology transfer to individual schools. The design, procurement and fielding of Local Area Network (LAN) technology is required in order to capitalize upon Wide Area Networking (WAN) benefits. The internetworking of schools creates a regional network but does not necessarily provide access to Internet data and information outside of that region. The next question then becomes "how do you build local area networks and connect them to form a wide area

network with Internet access?" Again the single overriding constraint is educational finance (taxpayer dollars).

Provided that these questions can be answered and implemented, the question that immediately follows is how to support the network and the end users. An information system must be supported in order to remain effective. Network faults will need to be diagnosed and repaired. Users will require training and technical support for their Local Area Networks (LANs). Typically solutions are manpower intensive. Where is the trade-off between short-term investment costs and long-term management costs. In short, "how do you ensure that Monterey BayNet will succeed"?

The scope of the Monterey BayNet project is so large that resolution of many important issues has been delayed in favor of achieving short-term goals. First among these goals has been getting schools, teachers and students on-line. We are successfully achieving that goal. This thesis will answer three research questions, and lay the foundation for a fourth.

- What are the end user needs?
- How do you cost-effectively build Local Area Networks (LANs)?
- How do you cost-effectively connect the 43 Monterey BayNet sites using PacBell services and Internet access in a Wide-Area Network (WAN)?
- How do you ensure that Monterey BayNet will be sustainable?

Follow-on research [Trepanier, 95] will address wide-area network management issues in greater detail.

IV. SOFTWARE APPLICATION SELECTION

A. INTRODUCTION

This chapter explains the importance of understanding end user information system requirements. End users will interact with the applications running on their networks, not with the technology on their desks. The I^{3}LA net design team spent time learning what the end user needed, determining which software would provide that functionality, and finally building software distributions of public domain programs that meet all user requirements for network-based education. Monterey BayNet's most important end users are teachers and students. Monterey BayNet also considers scientific researchers and the general public as important end users.

B. END USER REQUIREMENTS

A primary key to effective system development and implementation is the correct assessment of end user requirements [Whitten, 89]. The net design team derived end-user requirements from needs assessments in the supporting grant documentation [Matray, 94], and also from direct interaction with end users [Hudson, 94]. Requirements are summarized in Figure 4.1 and explanations follow.

- Full Internet access
- Videoconferencing capability
- Hypermedia technology: text, graphics, *PostScript* documents, archived audio and video
- Low cost
- Rapid network response to end user requests

Figure 4.1 End-user requirements.

Full access on the Internet is defined as "a permanent (full-time) Internet attachment running Transmission Control Protocol/Internet Protocol (TCP/IP), primarily appropriate for allowing the Internet Community to access application servers, operated by Internet providers" [Crocker, 95]. TCP/IP are the sets of software protocols (rules) which enable remote computers to directly connect to networks which are interconnected throughout the Internet [CDE, 94]. For example, *Trumpet Winsock* is TCP/IP software for *Windows* compliant platforms, and is freely available via File Transfer Protocol (FTP) download from *ftp.cica.indiana.edu* in directory *ftp/pub/pc/win3/winsock/twsk20b.zip*. *Winsock* is shareware requiring a $25 registration fee after evaluation [Tattam, 94]. Similarly, *MacTCP* is proprietary TCP/IP software for *Macintosh* platforms. The easiest way to obtain *MacTCP* is through the purchase of *The Internet Starter Kit for the Macintosh* (currently $29.95) at many bookstores [Engst, 94]. *MacTCP* is also provided with the *Macintosh* operating system 7.5.

Videoconferencing across the Internet is possible using a number of differing applications. The net design team is currently conducting research with the Multicast Backbone (MBone) which allows one-to-many communications [Macedonia, Brutzman, 94][Emswiler, 95]. MBone software is not yet available for *Windows* and *Macintosh* platforms but is expected. An interim videoconferencing tool (also free) is CU-SeeMe [Cogger, 94]. CU-SeeMe allows point-to-point connections between both *Macintosh* and *Windows* platforms.

Interactive technology refers to World-Wide Web (WWW) graphical browsers such as *Mosaic* [NCSA, 94] and *Netscape* [NCC, 95]. These tools allow easy access to hypertext and multimedia information. Widespread availability of these effective and user-friendly tools has revolutionized use of the Internet.

Members of the net design team met to identify a suite of publicly available applications which would meet end user needs in both the *Macintosh* and *Windows* environment (Appendices A, B). Choosing and evaluating applications from publicly available freeware and shareware ensured that software cost was minimal. The final software and corresponding functionality recommendations are shown in Table 4.1.

Interestingly, these choices are a superset of what is recommended for National Information Infrastructure compliance (NII) [NRC, 94].

FUNCTIONALITY	*WINDOWS* APPLICATION	*MACINTOSH* APPLICATION
Graphical Web Browser	*Netscape*	*Netscape*
Mail Client	*Eudora*	*Eudora*
Usenet Newsreader	*WinVN NNTP*	*Newswatcher*
File Transfer Protocol Tool	*WS_FTP*	*Fetch*
Virtual Terminal Access	*Trmptel*	*NCSA Telnet*
Gopher	*WinGopher*	*TurboGopher*
Image viewer/converter	*Lview*	*GIF converter*
Sound viewer	*Wham*	*SoundMachine*
Video file viewer	*Quicktime*	*Sparkle*
Data compression / decompression tool	*WinZip*	*StuffIt Expander*
Shared whiteboard application	*NCSA Collage*	*NCSA Collage*
SGML application	*HotMetal*	*BBEdit*
Video Conferencing	*CU-SeeMe*	*CU-SeeMe*
Virus Protection	*F-Prot*	*Disinfectant*
Network Diagnostics	*Ping*	*MacTCP Watcher*
PDF file viewer	*Adobe Acrobat*	*Adobe Acrobat*
PostScript file viewer	*GhostScript*	*GhostScript*

Table 4.1. Software functionality provided in final software distribution package.

Rapid network response, the final end user requirement, has two contributing elements. The first element is the data exchange rate (bandwidth) between the end user network and the Internet provider. This will be discussed in greater detail in Chapter VI.

The second element is the ability of the local computer to process the data provided from the Internet. To prevent poor performance and wasted investment the net design team established baseline personal computer hardware requirements for network access (Table 4.2). Platforms which do not meet or exceed the baseline will probably not perform well enough to justify the expense of a Network Interface Card (NIC).

***Macintosh* Personal Computer**	***IBM* Compatible Personal Computer**
Operating System 7.0 or better	Operating System Shell *Microsoft Windows* 3.0 or better
Minimum 68030 processor	Minimum 386 processor
Minimum 8MB RAM	Minimum 8MB RAM
Minimum 250 MB Hard Drive	Minimum 340 MB Hard Drive
Ethernet Capable	Ethernet Capable
Monitor - 256 color minimum	**Monitor**- 256 color minimum

Table 4.2. Minimum recommended PC hardware for K-12 schools [Herbst, 95].

The network design team also evaluated IBM's *OS/2 Warp* as a possible operating system shell for 386-based personal computers [IBM, 95]. *OS/2* is technically superior to *Windows* in a number of ways. However, the team decided to focus on *Windows* as the default environment due to wider use and familiarity among the schools. A recommended area for future work is to build an *OS/2*-based software distribution as an alternative for schools. A further alternative yet to be evaluated is *Linux*, the freeware *UNIX* operating system. Since *OS/2* and *Linux* can coreside with *Windows*, further opportunities for improved functionality at low cost are expected.

C. TECHNOLOGY PUSH-PULL

The end users in this case study are teachers and students. They are being placed in the position of responding to technology, rather than guiding the integration of technology. Funding to support connectivity is based upon a CalREN telecommunications access grant which expires in June 1996 [Matray, 94]. To achieve maximum benefit from the funding in a timely manner, some decisions have been made based upon assumptions that are not yet proven in practice. The "push" has been to quickly get the technology in the field so that we can use the connectivity and learn from our errors. All of the applications selected for the initial implementation will be reviewed after the end user has had the opportunity to evaluate their effectiveness in the educational environment. Thus the "pull" will be intellectual market forces and feedback from end users which produces an optimal software configuration. Enabling end users to upgrade and improve the recommended software build will make this process sustainable and allow continual improvement. Figure 4.2 provides definitions of technology push and pull.

- Technology Push - Educators responding to sudden technology introduction.
- Technology Pull - Educators requesting new technology based upon need.

Figure 4.2 Definition of technology push and pull.

D. ESTABLISHING REALISTIC END USER EXPECTATIONS

The technology "push" described in the previous section has often created end user resistance and confusion. Efforts to ease the strain of technology "push" have focused primarily on training. A pilot training session, "On-Ramp to the Super Highway" [Davis, 94], allowed 40 teachers the opportunity to receive "hands-on" training at the Naval Postgraduate School. The pilot session success led to a full scale "Virtual Night" [Sanders, 95] where 200 educators attended application demonstration sessions and later

had the opportunity to explore the Internet on their own. Educators with no previous exposure to the technology needed almost zero assistance beyond initial login procedures. These sessions, in addition to net design team software demonstrations on January 20th and 27th hopefully have contributed to ease the introduction of technology. Clearly they have helped to clarify end user expectations and create end user demand or "pull." Further hands-on demonstration events are planned in conjunction with the SIGGRAPH conference [Brutzman, 95] and other events.

E. SUMMARY

This chapter described the process by which the net design team developed the current end user requirements and the software suite to match. Installing the software and maintaining it will be discussed in Chapter VII. End user needs will change over time. A process similar to that discussed in this chapter will be required to recognize and manage changes to the software suite. Additional research is needed to determine the optimal use of technology in the K-12 community. The net design team has highlighted multi-media and videoconferencing applications. Further research can focus the requirements by determining, for instance, the system response time required to maintain student attention and interaction. It is strongly recommended that the effectiveness of the initial software load be evaluated by the end of the first year.

The most exciting and encouraging aspect of this entire project is that these are not merely theoretical problems. Real teachers and real students are beginning to use the technology to work on real problems. We expect to learn very interesting results.

V. LOCAL AREA NETWORK (LAN) DESIGN

A. INTRODUCTION

"What is a LAN? How do I build a LAN?" This chapter will provide all of the technical and background information required to build a sustainable local area network. The goal is to design a LAN which meets immediate user needs, and can be later expanded as user needs evolve. There is a great deal of information involved, but the planning and building a LAN itself is straightforward and appears in Figure 5.1.

- Appoint a Network Manager.
- Evaluate existing wire and cable paths for possible reuse.
- Make a site drawing which shows desired computer locations.
- Draw network using topology guidelines in this chapter and following existing cable paths.
- Derive equipment requirements from the site plan.
- Procure equipment (Appendix E).
- Install.

Figure 5.1 Local Area Network (LAN) planning methodology.

B. LOCAL AREA NETWORK (LAN) DEFINITION

A common misconception is that a LAN is the sharing of data, whereas in fact a LAN is merely the transmission path upon which sharing may occur. The *shared medium* is the physical infrastructure or cabling which makes up the backbone of every LAN. Here is one definition:

> The IEEE 802 LAN is a shared medium peer-to-peer communications network that broadcasts information for all stations to receive. The LAN enables stations to communicate directly using a common physical medium on a point-to-point basis. The network is generally owned, used, and operated by a single organization. [IEEE, 90a]

The idea of a shared medium is a key concept when planning a LAN. The infrastructure is the physical wiring of the LAN, over which all network devices communicate. A properly designed infrastructure can be flexible enough to support current and future networking needs. While cable itself is relatively inexpensive, the labor involved in installing cable or modifying existing cable runs can be daunting. Cable and hardware infrastructure quickly become the primary limiting factors in most LANs.

C. IEEE 802.3 CSMA/CD: ETHERNET

Every networked device requires some method of gaining access to the LAN shared medium. The IEEE 802.3 Medium Access Control (MAC) method is Carrier Sense Multiple Access with Collision Detection (CSMA/CD). CSMA/CD is a contention technique which allows devices to compete for medium access. The CSMA/CD function is physically performed by each device's Network Interface Card (NIC), commonly called an Ethernet card.

A common analogy for describing low-level CSMA/CD functionality is that of a dinner conversation in the dark. Each guest wants to speak but can not see the other guests. In order to communicate a guest must listen for silence, and then start speaking. This is analogous to the *carrier sense* mode. *Multiple Access* refers to the fact that every guest can contend for transmission time. Occasionally two guests will start speaking simultaneously and then have to stop. This is the *collision detection* mode. When a collision is sensed both guests will stop speaking, listen for silence for an independently random time, and resume talking.

The nature of the MAC method requires that there be some additional constraints placed upon the LAN. To continue the analogy you can imagine that there would be a limit to how long the dinner table might be, or how many guests might easily converse. These limits are summarized in Table 5.1. Fortunately the specifics of how devices interact over a shared medium are ordinarily transparent to end users. Knowledge of

low-level network functionality is not necessary for users who only want to run network applications.

Ethernet Type	Transmission Medium	Data Rate (Mbps)	Maximum Segment Length (m)	Maximum Nodes per Segment
10BASE5	Coaxial Cable (.4 in dia.)	10	500	100
10BASE2	Coaxial Cable (.25 in dia.)	10	185	30
10BASE-T	Unshielded Twisted Pair	10	100	2

Table 5.1. IEEE 802.3 physical layer specifications [IEEE90b].

10BASE5 Ethernet (commonly known as "ThickNet") uses standard baseband coaxial cable as its shared medium. It is not commonly found in use due to high installation and maintenance cost. ThickNet design guidelines are beyond the scope of this thesis. 10BASE2 Ethernet, also known as "ThinNet" or "Thin Coax" offers many of the advantages of ThickNet with lower cost and easier installation. Bus topology makes 10BASE2 ideally suited for use in network backbone applications. 10BASE2 Ethernet uses .25 inch diameter Coax (RG-58A/U or RG-58 C/U) cable as the shared medium. 10BASE-T Ethernet uses Unshielded Twisted Pair (UTP) wire in star physical topology as the shared medium. Most existing telephone-based customer premises wiring plants resemble star physical topology. Most schools in Monterey BayNet use 10BASE-T.

D. SHARED MEDIUM SELECTION

In addition to the design restrictions discussed above, the type of shared medium chosen will impose growth limitations upon the LAN. It is important to understand that the 802.3 Ethernet standard enables LAN communications at data exchange rates up to 10Mbps. 100BASE-T is currently under development and will enable data exchange rates of up to 100Mbps, but only if the shared medium (i.e. the cable) will support 100Mbps. Media transmission rates are summarized in Table 5.2.

Cable Media	Maximum Transmission rate (Mbps)	Approximate cost per foot (1995 pricing)
RG-58	10	$ 0.26
CAT-1 UTP	1	$ 0.03
CAT-2 UTP	4	$ 0.05
CAT-3 UTP	16	$ 0.10
CAT-4 UTP	20	$ 0.16
CAT-5 UTP	100	$ 0.18

Table 5.2. Cable media transmission rates and approximate cost.

Category 1 and 2 UTP are low-data-rate cables which can not support 802.3 Ethernet. Since labor is the primary cost in cable installation, it is recommended that any new cable installations use category 5 UTP for future growth. Nevertheless, there is rarely any technical need to upgrade category 3 or 4 wiring already in place. Category 5 UTP upgrade will be required only if 100Mbps Ethernet evolves as a mature technology and user needs dictate faster LAN transmission rates. Installation of category 5 UTP where new cabling is required allows maximum flexibility for future expected requirements.

E. SITE EVALUATION AND END USER BUY-IN

The final asset which must be considered in LAN design is the physical site itself. A simple map or blueprint of the building or buildings is essential, as is an understanding of existing cable paths (conduits) connecting these structures. If such a map is not available it will be necessary to create one by tracing, hand-over-hand, the cabling in place. A detailed discussion of local building codes can ordinarily be found at the local city planner's office. In general it may be assumed that cabling connecting buildings or running through an exposed outdoors environment needs to be contained in a conduit. The local physical plant engineer or building manager will likely be knowledgeable about additional local regulations.

A single point of contact on site must be appointed as the network manager. This person will need to maintain full knowledge of the premises wiring and network configuration. Initially this job will not require much time. As network grows and becomes more complex this may evolve into a sizable task. Without a single individual who is interested and involved, a growing LAN will quickly be at the mercy of paid consultants. The simple knowledge of how an infrastructure is connected can save many hours of consultant fees.

Since the LAN is going to be a part of the larger Internet it will eventually have to be connected to a Wide-Area Network (WAN). The equipment required to connect to the WAN is discussed in the next chapter. A logical starting point for LAN design is to begin at the service provider's Minimum Point Of Entry (MPOE). This is the first telephone panel inside the site premises after the telephone pole. PacBell identifies the MPOE with a green "MPOE" tag. Existing telephone services are already configured in a star physical topology. It may be possible to use existing excess capacity in the locally distributed telephone wiring to service your LAN. For this to occur the following must be determined to be true:

- Existing wire is 24-gauge, unshielded, twisted-pair, solid-conductor, Category 3 or better.
- 2 unused twisted pairs are available to each end location.
- The twisted pairs are free of splices.
- The maximum length of the 2 twisted pairs is 100 meters.

Given a good understanding of existing physical infrastructure, LAN designers are able to determine where additional cable needs to be installed. The next two sections contain guidelines for planning a network topology to meet user needs. It is important to plan for future expansion throughout the entire facility, not just to meet immediate needs.

F. 10BASE-T DESIGN GUIDELINES

10BASE-T network design is based upon star topology (Figure 5.2). 10BASE-T operates over 2 pairs of wire, one pair used for receive data signals and the other for transmit data signals. The wire must conform to EIA/TIA Category 3 (or greater) wire specifications and follow the EIA/TIA-568B wiring scheme (Appendix C) [EIA/TIA-568].

Every UTP segment is connected to exactly two nodes and segment length is limited to 100m (328ft). The term "star" comes from the physical topology created when a number of nodes are connected using 10BASE-T repeaters, also called hubs or concentrators (Figure 5.3). Hubs allow multiple node inputs to be concentrated into a single output. Recall that the Ethernet MAC method is CSMA/CD. Thus the job of the hub is merely to amplify an incoming signal from any node and rebroadcast it to all other nodes.

There are limitations on the number of repeaters and cable segments allowed between any two stations on the network. The "5-4-3 Rule" states that "there may be no more than five (5) repeated segments, nor more than four (4) repeaters between any two nodes, and of the five cable segments, only three (3) may be populated" [IEEE, 90b]. The term "populated" refers to a segment which connects two hubs.

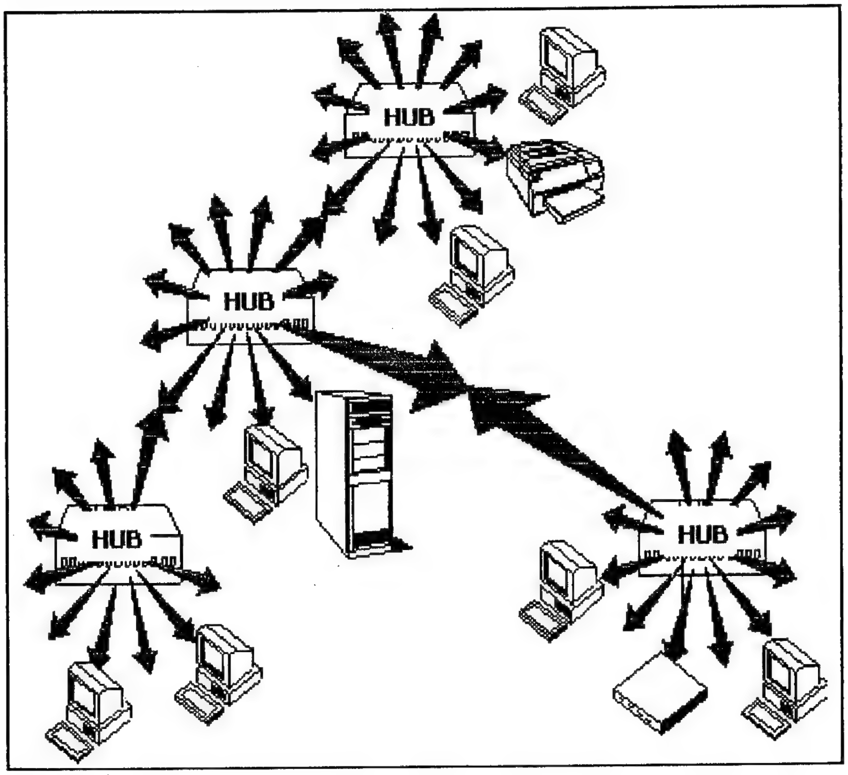


Figure 5.2 Conceptual 10BASE-T star topology.

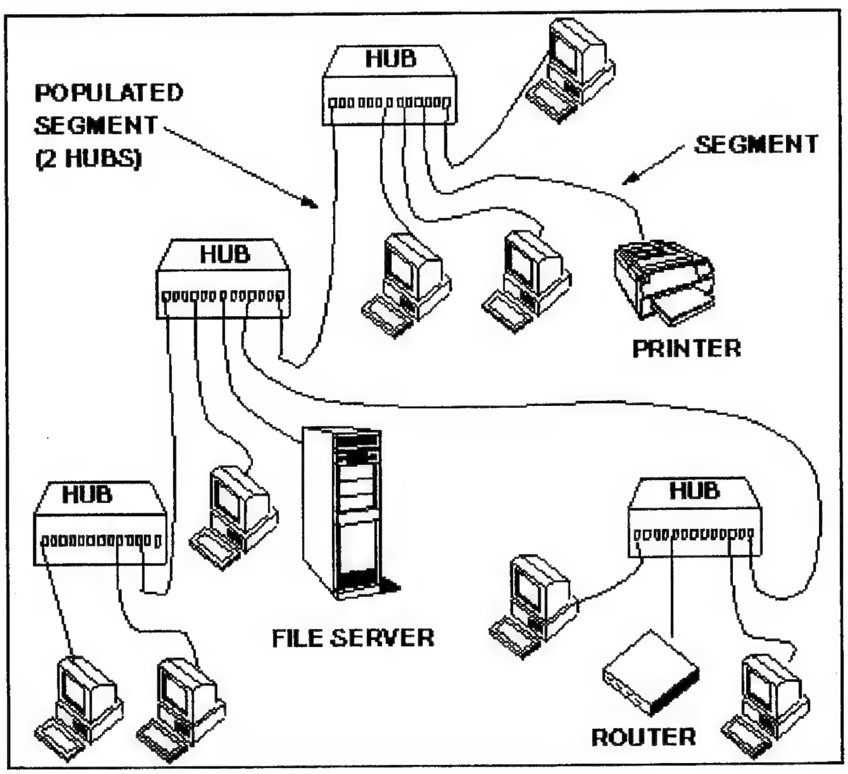


Figure 5.3 Physical 10BASE-T star topology.

Commercial hubs are available with up to 48 ports. In designing the LAN ensure that purchased hubs have more capacity then is currently needed. This will allow for future expansion and greater flexibility. The Ethernet theoretical maximum is 1024 nodes per 10BASE-T network [IEEE, 90b].

G. 10BASE2 DESIGN GUIDELINES

10BASE2 network design is based upon bus topology. On a bus or *backbone* a single coaxial cable acts as the shared medium for all nodes. Signals broadcast from a node travel in both directions the length of the bus and can be received by all nodes [Stallings, 94]. The coaxial cable is actually composed of 2 to 29 cable lengths, each no shorter then .5m (20in). Cable lengths are joined at each node with male BNC 'T' connectors (Figure 5.4). Note that each 'T' connector is attached directly to a node's NIC. By definition the distance between each node and the bus can not exceed 4cm (the depth of the BNC 'T' connector) [IEEE, 90b].

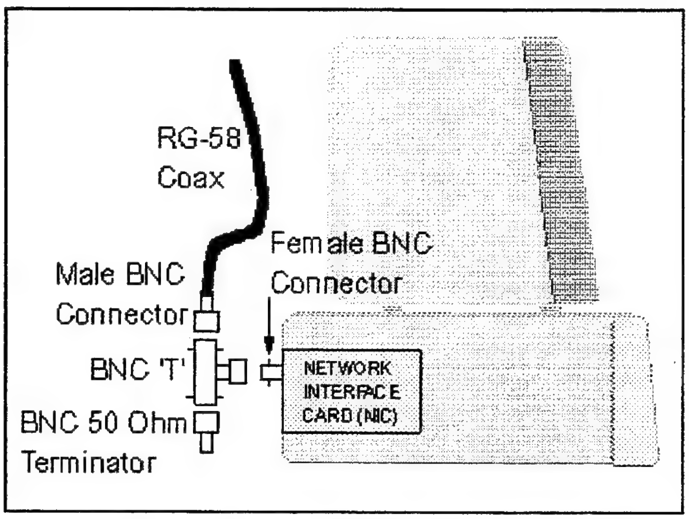


Figure 5.4 BNC "T" connection to node.

Each full segment can be no longer then 185m (606ft) and must be terminated at each far end with a 50 ohm BNC terminator to provide circuit continuity. Each single segment can contain no more than 30 nodes and 2 terminators (Figure 5.5).

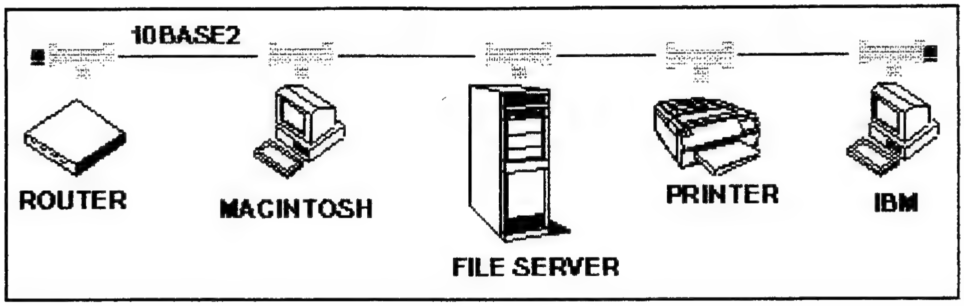


Figure 5.5 Single segment 10BASE2 network.

Multiple 10BASE2 segments can be joined using repeaters (Figure 5.6). The "5-4-3" rule discussed in the previous section applies to 10BASE2 networks as well. A maximum of four repeaters are allowable creating an overall maximum 10BASE2 span of 925m and 150 nodes [IEEE, 90b].

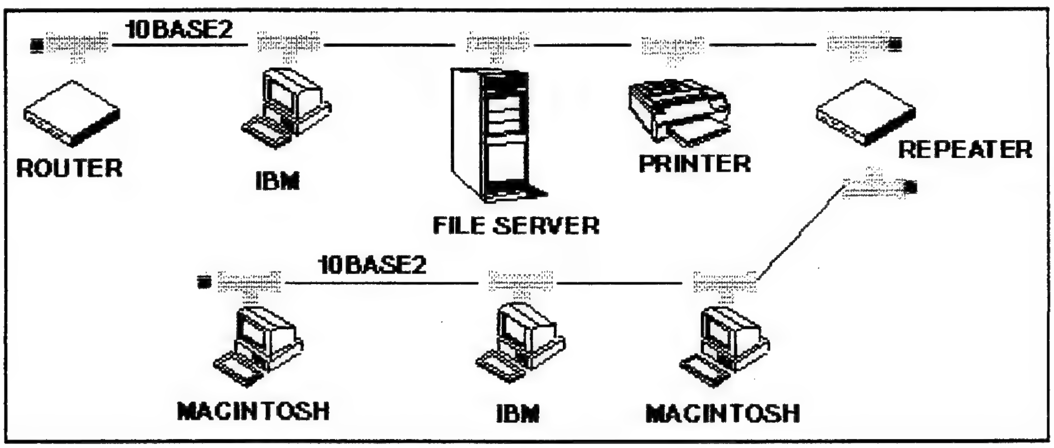


Figure 5.6 Two segment 10BASE2 network.

H. 10BASE-T / 10BASE2 COMPARISON

10BASE2 network installation is attractive in that it saves the initial expense of purchasing multiple hubs. It is relatively easy to install and removing a node does not affect the rest of the network. 10BASE-T is slightly more expensive initially, but it is far more expandable and cost-effective in the long term. If Category 5 UTP wiring is in

place, an upgrade from 10BASE-T to 100BASE-T is possible. The 10BASE2 infrastructure cannot be upgraded to support 100Mbps without installing new cabling.

Beyond installation cost is the cost of preventive and corrective maintenance. A malfunctioning node on a 10BASE2 bus can affect all other devices connected to the bus. Troubleshooting can be difficult and time consuming. The usual method of fault isolation involves disconnecting devices one at a time until the faulty node is discovered. In comparison, a 10BASE-T network node which malfunctions is easily found and isolated from the rest of the network. Indication lights on the 10BASE-T hubs make it a simple matter to troubleshoot large networks. Appendix D contains a variety of example LAN designs implemented in the performance of this thesis.

I. EQUIPMENT SELECTION

There are numerous vendors that sell IEEE 802.3 Ethernet products. It is important to standardize the equipment used in a network. Standardization of Monterey BayNet occurred throughout the two counties, not just within individual schools. This will allow all of the end users to become familiar with the strengths and oddities of a single product, rather than confuse them with multiple differences between platforms. Appendix E describes the Monterey BayNet equipment recommendations. These recommendations serve two purposes. They simplify the management of the WAN, and they make troubleshooting easier for the individual members of the WAN.

1. Simple Network Management Protocol (SNMP)

"Intelligent" networking devices are those devices which are able to operate as Simple Network Management Protocol (SNMP) agents [Case, 90]. Devices which can have this ability include:

- Hubs
- Routers

- Network Interface Cards
- Peripheral Devices
- Channel Service Unit (CSU)/Digital Service Unit

SNMP compatibility greatly enhances a network administrator's ability to monitor and correct problem areas within the LAN. SNMP agents report their status periodically and upon request to a management station. The management station in turn can send orders back to the agent, correcting errors detected in the LAN.

Maintenance of a SNMP management station is often beyond the ability of LAN managers. That responsibility can be passed up to the WAN manager. If the WAN manager acts as the management station for all attached LANs, economies of scale may be achieved which make overall network management cost effective and improve system reliability. The additional cost of SNMP capability is nontrivial but SNMP compatibility is an essential component of LAN design. It is less expensive to purchase SNMP capability "up front" than to upgrade equipment in place. These issues will be examined in further detail in *"Wide-Area Network (WAN) Management: A Case Study"* [Trepanier, 95]. A new proposed standard for SNMP Version 2 which extends current SNMP capabilities is discussed in RFC 1441 [Case, 93].

2. Proprietary Technology

The IEEE 802.3 standards provide minimum technical guidelines which many manufactures have been able to exceed. Some of these products allow communication over greater distances or through lower grade media. These products may be useful to provide technical solutions for situations where distance constraints or media restrictions prevent compliance with 802.3 specifications. Never the less, the LAN planner must avoid deviation from minimum specifications whenever possible. The purchase of proprietary non-standard equipment usually creates a situation where the LAN manager limits future upgrade possibilities and commits to a sole source of proprietary hardware. Such a situation is extremely undesirable.

3. LAN Operating Systems

A LAN operating system is required if users desire the added functionality of being able to share a single copy of a "networked" software application throughout the LAN. This makes a great deal of sense in that a single site license for X machines is normally cheaper than X copies of that software. This approach also frees hard drive disk space on individual computers, usually by putting the single copy of site-licensed software on a file server.

Each individual computer has its associated operating system, ordinarily MS-DOS 6.1 or better on IBM platforms, and System 7.1 or better in the *Macintosh* world. A LAN operating system is software, normally resident on a file server, which enables LAN clients to share software applications resident on that file server [Long, 93]. *Macintosh AppleTalk* [Apple, 95] and *Microsoft Windows for Workgroups* [Microsoft, 95] are two examples of LAN operating systems which enable shared applications in a single operating system environment without the additional expense of a dedicated file server. In a LAN environment with mixed operating systems, a more robust LAN operating system such as *Novell Netware* will be required to enable shared applications across multiple platforms. Configuration of *Novell Netware* or equivalent normally requires the service of a Certified Network Engineer (CNE).

J. LAN DESIGN SUMMARY

The focus of this chapter has been on building a LAN with the supporting infrastructure to make it expandable for future growth. 10BASE-T is the preferred solution. The most cost-effective implementation utilizes existing excess telephone lines reaching to the classrooms. Excess lines are not always available and often new cable is required. The high dollar item in cable installation is the labor involved in installing the cable. The California Department of Education (CDE) recommends pulling coax for cable television at the same time that Category 5 UTP is pulled for the LAN [CDE, 94]. The actual wiring of the RJ-45 ports and 8-position modular plugs requires more patience than

skill. A crimping tool and 10BASE-T tester are required items and can be found at any major electronics outlet.

Figure 5.7 outlines some of the more common pitfalls encountered on the way to successful implementation. Avoid them! Chapter VI will discuss the equipment required to connect a LAN to the WAN. In LAN design, the WAN connection is "just another node" which happens to be at the MPOE. Do not forget to include the WAN connection in the site plan.

- Do not violate 802.3 specifications - system degradation will result from crosstalk, lost packets and excess collisions.
- Do not use splices, the 100 meter rule is actually expressed in decibel loss. Splices degrade signal strength.
- Do not mix and match equipment, pick a single standard product.
- Avoid proprietary solutions.
- Label all wires and maintain a detailed record of the network.
- Verify that equipment ordered has the desired connectors. Inexpensive hubs often require external transceivers for AUI connections.
- Test every connection during and after installation.
- Verify that there are only two terminators in every 10BASE2 segment.

Figure 5.7 Correcting common mistakes in LAN installation.

Many opportunities exist to continue research in the K-12 LAN design area. Fiber Distributed Data Interface (FDDI) backbone topology is becoming increasingly cost effective and may provide a migration path for schools with widely distributed campuses. Another LAN technology which deserves examination in the K-12 community is the emerging wireless LAN. While still more expensive than wired LANs, wireless technology may provide a migration path for schools with unique needs. Finally the likely deregulation of the telecommunications industry may soon narrow the dividing line between telephone provider and cable television provider. Technology exists which can carry both television and LAN data traffic over existing cable industry coax. As these technologies continue to evolve they need to be examined to determine if they are cost-effective and scalable in the K-12 community.

VI. WIDE AREA NETWORK (WAN) DESIGN

This chapter reviews the telecommunications services available for WAN connectivity, and the net design team's justification for selection of Frame Relay. Internet service provider selection is discussed briefly, as well as the equipment selection and the group purchase technique used. After reviewing the supporting decisions a coherent WAN design is presented. The chapter concludes with an overview of the Monterey BayNet IP addressing schema, autonomous system (AS) registration and domain name registration procedures.

A. WAN DESIGN PROCESS INTRODUCTION

Figure 6.1 attempts to provide an ordered view of WAN design. The network design team experience in creating Monterey BayNet has shown that most of these decision points happened almost simultaneously. The decisions are highly interdependent, making the designation of network administrators critical. In the case of Monterey BayNet the network administrators are the County Offices of Educations (COEs). The participating LANs are 43 CalREN member sites.

- Assign Network Administrator
- Identify Participating LANs
- Evaluate and select communications mode
- Select Internet provider
- Select required hardware
- Model WAN topology
- Assign IP addresses
- Assign domain names
- Determine routing and routed protocols
- Implement

Figure 6.1 WAN planning steps.

The following sections provide background information and describe the decisions of the network design team. In most cases the network design team considered a range of options. There are also options which may not have been considered or that this author has chosen not to include. The success of the process at an individual site lies in the network administrator's careful consideration of all options in cooperation with the Internet provider and hardware manufacturers. The success of the process regionally has been due to the open and collaborative sharing of questions, problems and answers. Individual sites might have proceeded more quickly if they pursued independent approaches, but it is highly unlikely that any uncoordinated LAN/WAN plan might be more reliable, robust and well-suited to all Monterey BayNet members.

B. TECHNOLOGY OVERVIEW

There have been a number of advances in computer network reliability and digital technology in the past decade. These advances have made extremely high rates of data transfer (bandwidth) possible in a WAN environment. The net design team reviewed four service options available through PacBell for WAN connectivity. The criterion for selection included adequate data transfer rates for hypermedia, the potential to sustain videoconferencing via MBone, ease of upward transition when demand increases in the future, and long-term access costs to the end user after the CalREN grant expires.

1. Asynchronous Transfer Mode (ATM)

ATM, also called Cell Relay, is an ultra-high-speed switching and transmission fabric which is intended to form the high-performance portion of the Monterey BayNet. The ATM portion of BayNet will be distinct from lower-bandwidth portions of BayNet [I^{3}LA, 94]. PacBell's ATM service offering will initially operate from 45 Mbps (DS-3 lines) to 155 Mbps (OC-3 lines), evolving to the gigabit per second (Gbps) range (billion bits per second) [PacBell, 95]. ATM differs from Frame Relay through the use of fixed

length packets called cells. The reduction achieved in individual cell overhead allows greatly improved data transmission rates [Stallings, 94]. A good introductory reference to ATM is *Asynchronous Transfer Mode Networks: Performance Issues* [Onvural, 94].

2. Switched Multimegabit Data Service (SMDS)

Switched Multimegabit Data Service (SMDS) is a public, cell-switched service offering high-performance data transmission [Sprague, 93]. Pacific Bell's current SMDS offering include transmission rates from 1.5Mbps (T1 line) to 45Mbps (T3 line) [PacBell, 95]. SMDS differs from ATM through its use of the public switched network. The net design team did not recommend the use of SMDS because 1.5Mbps to 45 Mbps connectivity to schools appeared excessive and expensive. Table 6.1 lists PacBell tariff rates for single LATA SMDS service [PacBell, 95].

Data Rate	Installation	Monthly
1.17 Mbps	$1009	$775
4 Mbps	$7300	$5700
10 Mbps	$7300	$6700
16 Mbps	$7300	$7200
25 Mbps	$7300	$7700
34Mbps	$7300	$8200

Table 6.1. SMDS intra-LATA service tariff [PacBell, 95].

3. Integrated Services Digital Network (ISDN)

ISDN is a standardized telecommunications network architecture providing multi-channel, integrated end-to-end connectivity. ISDN allows the high-speed

transmission of digital information through a single customer interface, whether the content is voice, data, video or graphic images [PacBell, 95]. Basic Rate ISDN (BRI) provides two full 56 Kbps unrestricted "B" channels for voice or data and one 16 Kbps "D" channel for signalling and data, on a single line. To the end user ISDN service will act "just like" telephone service. The service is digital so there is no need for a modem, but terminal adapter (TA) hardware is required and "calls" are still placed linking the user to the target host.

Pacific Bell has three rate structures for BRI ISDN service: SDS, Centrex, and Home. SDS pricing is the rate structure which would apply for most schools attempting to connect to a nearby County Office of Education (COE). ISDN, like telephone service, has usage-based pricing and may incur long-distance charges depending upon the location of the caller and destination. Local usage is charged at the rate of $0.04 for the initial call and then $0.01 for each minute per "B" channel [PacBell, 95]. Table 6.2 lists the SDS ISDN charges. The actual monthly cost of an ISDN connection may be highly variable due to usage and long distance charges.

	Installation	Monthly	Usage (100 Hours)
Two 56 Kbps "B" Channels	$70.75	$24.82	~ $120 +

Table 6.2. PacBell SDS ISDN rate. [PacBell, 95]

For technical reasons Primary Rate ISDN (PRI) appears to be the best ISDN choice for schools. PRI provides scalable upgrades in capacity from 128 Kbps all the way to 1.5 Mbps (T1) at 64 Kbps increments (i.e. "fractional T1"). Basic Rate ISDN (BRI) is unacceptable since the 128Kbps bandwidth limit is too low, and since BRI equipment is generally incompatible with PRI equipment.

Long-term use of ISDN by schools will require a predictable and affordable rate structure for connectivity charges. Interoperability concerns will hopefully be fixed when equipment vendors implement Multi-link PPP protocol [Sklower et al., 94], an open

standard that will ensure compatibility and avoid unacceptable proprietary software restrictions. Until these two problems are fixed, ISDN is not a practical solution for providing school connectivity. Figure 6.2 summarizes the impediments that prevented the net design team from recommending ISDN for school use:

- Basic Rate Interface (BRI) ISDN is unacceptable due to low bandwidth with no compatible upgrade path.
- Current high cost of Primary Rate ISDN is out of reach for schools.
- Vendor hardware solutions are proprietary and not interoperable. Multilink PPP may resolve this, but has not been implemented [Sklower et al., 94].

Figure 6.2 Deficiencies preventing endorsement of ISDN use in Monterey BayNet.

4. Frame Relay Bearer Service

Frame Relay bearer service is a connection-oriented, virtual circuit service. PacBell's current Frame Relay service offers transmission rates from 56 Kbps to 1.544 Mbps, increasing in 56Kbps increments [PacBell, 95]. The Frame Relay protocol achieves increases in speed beyond its predecessor X.25 transport protocol by performing error correction only at the origin and destination [Sprague, 93]. Frame Relay is a data link layer protocol which can operate over ISDN or Frame Relay bearer service, although Frame Relay protocol implementations over ISDN are not currently offered by Pacific Bell [Chen, 89][Sprague, 93]. For the purposes of this thesis, Frame Relay will imply Frame Relay protocol over Frame Relay bearer service.

Frame Relay is offered as a flat-rate, distance-insensitive service. These attributes make Frame Relay an ideal service for connecting regional LANs, particularly in the education sector. Flat-rate pricing (Table 6.3) leaves no budgetary doubt for school boards in planning their information technology budget. Distance insensitivity assures that there are no down-stream long-distance charges to be applied on top of the flat rate.

Data Rate	Installation	Monthly	Monthly (2 PVC)
56 Kbps	$1005	$125	$140
128 Kbps	$1009	$325	$340
384 Kbps	$1009	$575	$590
1.544 Mbps	$1009	$675	$690

Table 6.3. Frame Relay service flat rate tariff. [PacBell, 95]

C. SELECTION JUSTIFICATION FOR FRAME RELAY

The network design team selected Frame Relay as the WAN connectivity service because it offered greater access speeds, economy, and a clear transition path for increased bandwidth. The selection was not intended to rule out ISDN usage in Monterey BayNet. ISDN has some advantages over Frame Relay in home dial-in access and in studio quality videoconferencing. Several sites are proceeding with the installation of both Frame Relay WAN connectivity and ISDN lines for comparison.

1. Access

The ability to use high-bandwidth Internet applications like *Netscape*, *Mosaic* and the MBone tools have been a primary driver of the network design. Ordinarily the minimum acceptable bandwidth for MBone is 128Kbps [Macedonia, 94]. PacBell BRI ISDN is limited to 112 Kbps [PacBell, 95]. PacBell Frame Relay services range from 56Kbps through 1.5Mbps, making high-bandwidth access feasible.

A second consideration to the access equation is the bandwidth of the connection from the County Office of Education (COE) to the Internet provider. Bottlenecks can occur in a purely BRI ISDN-based WAN because all lines out of the COE can be the same size as the line between the Internet Provider and the COE. In the case of Monterey BayNet, full T-1 Frame Relay service to the COE greatly reduces the likelihood of

congestion. The methodology for designing this topology will be presented later in this chapter.

2. Economy

At the site level ISDN initially seems like the clear price leader over Frame Relay. Equipment costs for both technologies are similar. The difference becomes clear when usage rates and long distance charges are estimated. Frame Relay costs are time and distance insensitive. Monthly basic rate ISDN charges, without long distance charges, exceed the 128Kbps Frame Relay charges at approximately 250 hours of usage. In a network environment 250 monthly hours is quite possible, particularly if the site wants to operate a server that is accessible via the Internet around the clock.

At the county level the economic distinctions are even clearer. An ISDN-based WAN requires an ISDN line for each site connecting at the county office. Twenty BRI lines with 100 hours of average usage would cost $2896.40 monthly, compared to T-1 access at only $960 per month ($690 per month + $15 for each additional DLCI) [PacBell, 95].

The cost of a router which can connect 20 BRI lines is significantly greater than the cost of a Frame Relay router supporting any number of virtual circuits. Further savings result because the Frame Relay-based WAN needs hardware for only one physical WAN connection, compared to 20 in the ISDN topology. The benefit is greater simplicity, lower router costs, lower communications hardware costs, and lower line costs [Lloyd, 94].

3. Transition to Higher Bandwidths

Multiple ISDN 'B' channels can be linked to increase bandwidth using devices called inverse multiplexers. "There are (currently) no good *nonproprietary* ways to combine the two 64Kbps bearer ('B') channels into a single logical 128Kbps channel"

[Lloyd, 94]. The current proprietary solutions which do exist are not compatible across manufacturers. ISDN Internet providers resolve the compatibility issue by strictly specifying the access hardware which is known to work with their system.

In contrast to ISDN, Frame Relay hardware specifications are widely accepted and interoperable products are offered by numerous vendors. PacBell supports dedicated 56Kbps Frame Relay bearer service over advanced digital network (ADN) lines. Fractional T-1 lines (128Kbps through 1.5Mbps) are provided by High Capacity Digital Service (HiCap). A T-1 line is composed of twenty four 64Kbps channels. A channel service unit (CSU) is used to aggregate channels, offering a range of service from 128Kbps through 1.5Mbps. No additional hardware is required to increase bandwidth beyond 128Kbps. The network design team does not recommend 56Kbps Frame Relay service because it will not support nominal MBone transmission rates and future upgrades to 128Kbps or above will require the purchase of new CSU hardware and installation of a new HiCap line.

D. FRAME RELAY NETWORK CONNECTION DETAILS

Frame Relay is a data link layer, packet switched, multiplexed data networking technology. The Frame Relay network is based upon the routing of *frames* (Figure 6.3) by a data link control identifier (DLCI) value [Stallings, 94]. Information of variable length is encapsulated in the frame, to be opened at the destination. Routing is accomplished by forwarding frames across a permanent virtual circuit (PVC) to the location specified by the DLCI connection table. The table is maintained and updated by the Frame Relay switch. Figure 6.4 demonstrates how each site has a physical connection, yet can support multiple PVCs.

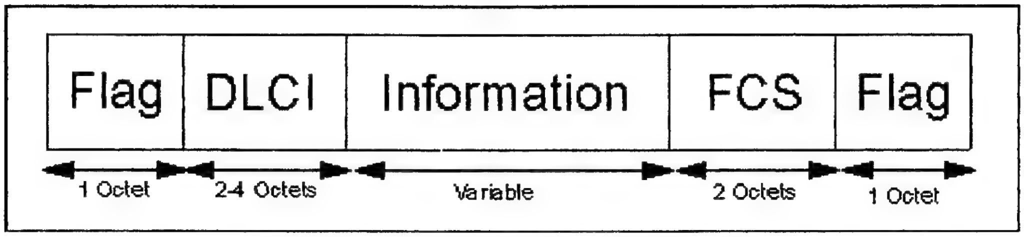


Figure 6.3 Frame format [Stallings, 94].

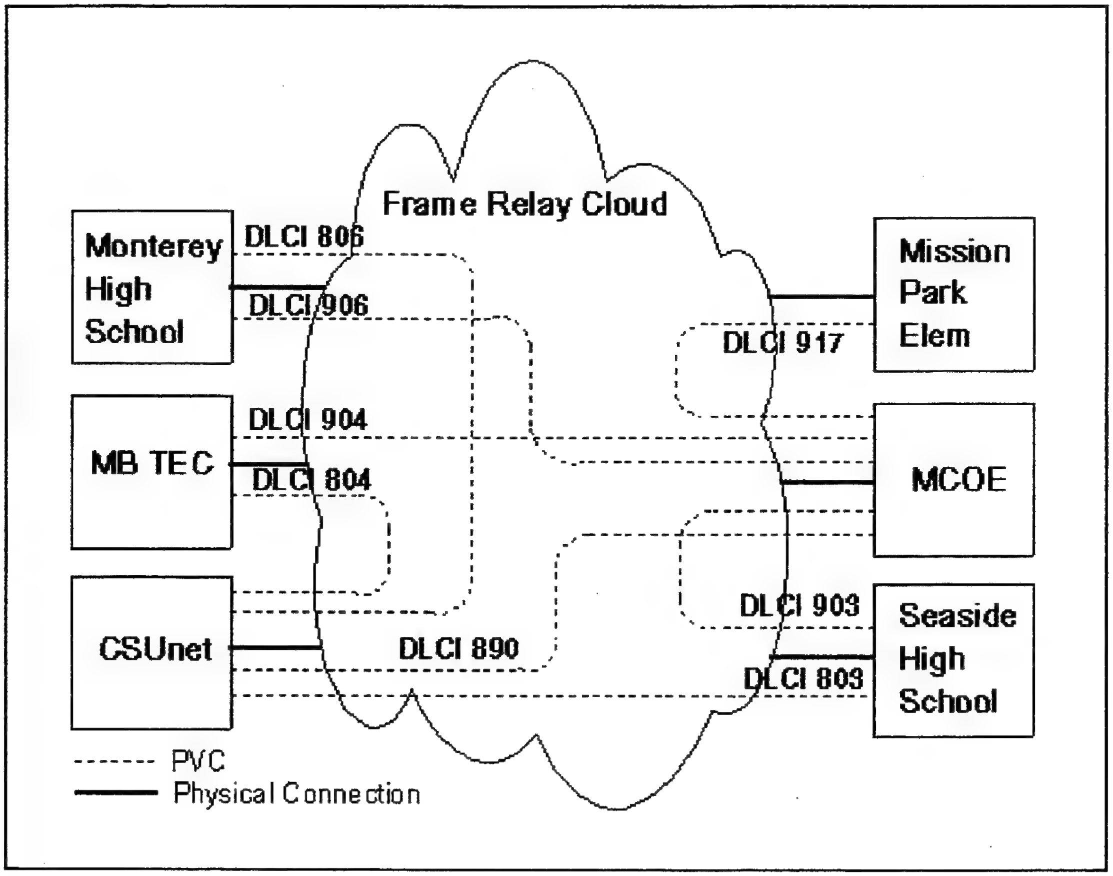


Figure 6.4 Example Permanent Virtual Circuits (PVCs) in the Frame Relay cloud.

The Frame Relay multiplexing function enables the creation of the multiple PVCs. Each end of a PVC is assigned a unique IP address, creating the interface between IP and DLCI assignment. Each PVC is assigned a committed information rate (CIR), i.e. a "worst case" data exchange rate.

The physical equipment needed on site to connect a LAN to a Frame Relay line is detailed in Figure 6.5. PacBell brings the High Capacity Digital Service (HiCap) to the MPOE and installs the Network Interface Unit (NIU). The port on the NIU has been disconnected so it is necessary to install an external RJ-48 connector. This can be installed by PacBell for a small charge or provided and installed by the user [PacBell, 95]. The RJ-48 does not have to be physically present at the MPOE. If the RJ-48 is not going to be installed at the MPOE then it is strongly recommended that PacBell do the installation. The demarcation line (also shown in Figure 6.5) is where PacBell's responsibility for maintenance ends. The demarcation line is determined by who installs the RJ-48. The physical wiring of the RJ-48 connector to the output of the Network Interface Unit (NIU) is detailed in Appendix F.

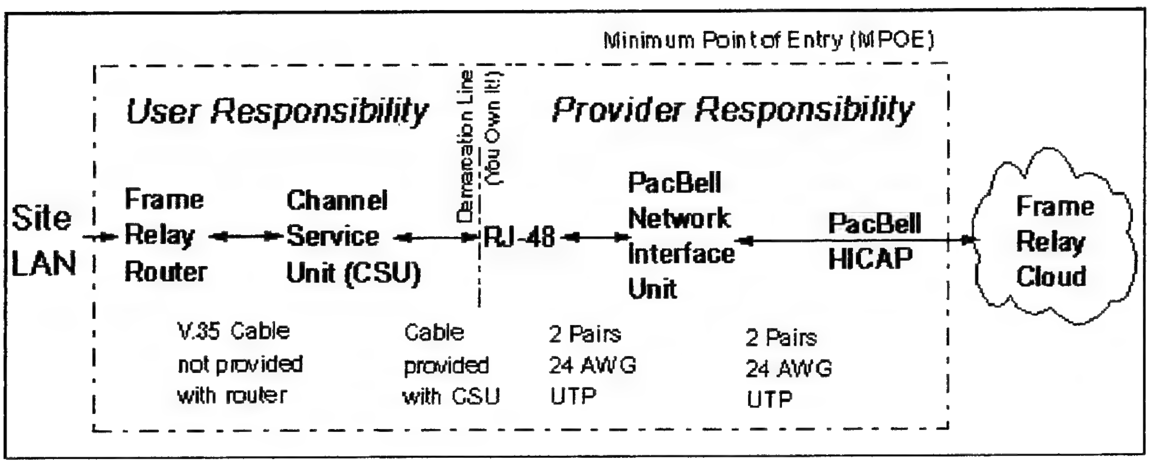


Figure 6.5 Equipment required to connect a LAN to the Frame Relay cloud.

An eight-position modular plug to eight-position modular plug is provided with the CSU for connection to the RJ-48. Connection to the router will depend upon the CSU and router specifications. The RJ-48, CSU and router must located together. Both the CSU and Router will require 110VAC from a standard electrical outlet. It is strongly recommended that all network hardware power supplies be protected with surge suppression devices. Surge suppression devices must have adequate amperage capacity (typically 30 to 40 amps) and meet *National Electrical Safety Code (NESC)* specifications

[ANSI, 1993]. Consideration might be given to the purchase of an Uninterruptible Power Supply (UPS). A UPS conditions power to filter out power spikes, surges and provide back-up power in the event of a brown-out or black-out. Surge suppressors merely protect the internal power supplies of connected devices by acting like an additional circuit breaker. The decision to purchase a UPS is a business decision, not a technical one. A UPS is recommended where the data that is being processed has value exceeding the cost of the UPS.

E. INTERNET PROVIDER SELECTION

Monterey BayNet spans two PacBell Local Access Transport Areas (LATAs). In this case the LATA boundaries generally follow county borders, with Santa Cruz in LATA 1 and Monterey in LATA 8 (Figure 6.6).

Figure 6.6 California LATAs [PacBell, 95].

PacBell is a local telecommunications provider. Telecommunication regulations prohibit local providers from crossing LATA boundaries. Only long distance providers such as AT&T, MCI or Sprint are authorized to connect local providers across LATA boundaries. Thus PacBell was initially prevented from providing dual LATA service. Despite this impediment the CalREN trust agreed to award a grant to the Monterey BayNet consortium. This presented Monterey BayNet with four options for connecting the two COEs.

- Establish a microwave link between two sites spanning the LATA boundary.
- Request regulatory relief from the California legislature.
- Hire a long distance provider to connect the COEs across the LATA boundary.
- Select an Internet provider which already has a inter-LATA agreement.

The microwave link is an attractive and technically feasible solution for connecting data networks. Use of the link might remove the need to hire a long distance provider, but setup cost is substantial. A proposal was discussed at length with California Senate Majority Leader Henry Mello that would allow PacBell an exemption in the case of Monterey BayNet inter-LATA traffic. The legislation was viewed favorably but alternative solutions were found which avoided the necessity of lengthy legislative effort. To avoid the additional expense of an inter-LATA bridge the network design team built two WANs which are virtually connected by the Internet. Internet provider selection was thus narrowed to providers having a presence in both LATAs and an inter-LATA agreement with a long distance carrier.

The Internet provider selection process was based primarily upon cost. After much debate the network design team recognized that, reliability issues aside, Internet access ought to be viewed as a commodity. Most Internet providers offer a range of services. Full service generally implies that the provider will include the cost of required hardware and data circuits as part of the activation and installation fees. Additionally the

Internet provider often assigns the Class C IP addresses for use by connected sites and provides 24-hour network monitoring and problem resolution to the site level [Baer, 94].

Monterey BayNet opted to install and maintain all member site connections. This decision was primarily driven by cost to the end user. WAN management for each county is, by default, the responsibility of the respective COE. Each COE hosts an Internet server and functions as the domain name server for the member sites. This configuration matches the recommendations of the California Department of Education's *Network Technology Planning Guide* [CDE, 94]. An alternative solution might have been the out-sourcing of installation and management functions to an independent contractor or an Internet provider. Monterey BayNet further reduced the cost of Internet access by locally designing, requesting and managing assigned IP address space and WAN connectivity [Trepanier, 95]. California State University Network (CSUnet) was contracted as the Internet provider. LATA 1 connectivity in Santa Cruz County to the CSUnet backbone is available through the Frame Relay cloud to San Francisco State University (SFSU) and LATA 8 connectivity in Monterey County is through CSU Monterey Bay (CSUMB). CSUnet's long distance carrier is SprintNet, creating the essential inter-LATA bridge required to connect the two COEs.

F. HARDWARE SELECTION

The physical management of hardware across the WAN is made much simpler by brand-name standardization. Note that this is not an interoperability issue but rather a network management sanity issue. Standardization allows end users to pool common resources and develop accepted fault isolation patterns. It also presents the opportunity for greater manufacturer discounts through group purchase. Coordinating a group purchase throughout multiple school district budgets is not trivial. The Monterey County Office of Education (MCOE) acted as central agent for the group purchase of DSUs and routers throughout Monterey BayNet. The network design team in conjunction with the Internet provider (CSUnet) played an advisory role in equipment selection for Monterey

BayNet. The equipment selected and corresponding functionality are described below. Selection was based upon cost, interoperability, reliability, reputation, and ease of use.

1. Channel Service Unit (CSU) Selection

The CSU acts to synchronize the frames being output from the router with the proper channels on the T-1 line. A T-1 line consists of 24 channels, each with a bandwidth of 64Kbps. A 128Kbps site uses channels 1 and 2, while a 384Kbps site uses channels 1 through 6. The CSU is configured by the user at the site. Increasing bandwidth requires only a telephone call to PacBell to order the increased line speed and Committed Information Rate (CIR). Locally the only modification required is a corresponding adjustment the CSU hardware settings.

Two different CSUs are used in Monterey BayNet. Those sites opting for 56Kbps ADN service install an *Adtran* 56/64 digital service unit (DSU). Configuration is completed by manipulating switches on the rear of the unit. Those sites installing a T-1 line will be using the *Adtran* T-1 service unit (TSU). Configuration is accomplished through a series of menu selections. Appendix G details the configuration settings for both devices. A eight-position modular plug to eight-position modular plug silver satin flat cable is provided with each device for connection to the RJ-48.

2. Router Selection

The net design team selected the *Cisco* 2500 family of routers for use by Monterey BayNet. The 2500 series offers a range of technology options to end user sites. The *Cisco* 2501 is currently the low price leader. A single LAN router, the *Cisco* 2501 is capable of meeting the needs of most of our sites. The *Cisco* 2514 provides dual LAN capacity for an additional investment of $350 [Cisco, 95]. The *Cisco* 2514 is recommended as an entry level router. The *Cisco* 2511 provides a single LAN connection and 16 asynchronous ports for dial-in access. An option for non-member sites

in the BayNet region is the *Cisco* 2503I, an ISDN router which can be upgraded to Frame Relay functionality. The 2503I provides a transition path for schools outside of CalREN who desire to connect to commercial Internet providers using free ISDN services offered by the Education First grant [PacBell, 94].

A V.35 male to female 34-pin connector is required to connect the CSU and the router. The cable is not provided with the router. All *Cisco* 2500 routers require external transceivers to connect the LAN to the router's Attachment Unit Interface (AUI) port. A sample router configuration script is provided in Appendix H.

3. Web Server Selection

The centralized Internet server for each COE is the *Lloyd Internetworking Cyberstation*. Most servers which have the ability to scale to the size of the Monterey BayNet require UNIX operating system capabilities. The *Lloyd Internetworking Cyberstation* is a *Sun SPARC* workstation with *Solaris* 2.3 operating system and a variety of specially configured software [Lloyd, 95]. It was selected because it offers a graphical user interface (GUI) over the operating system which makes network administration possible without UNIX experience. Additional bundled services include *POP2, POP3, IMAP, pine, elm,* WWW server, *xmosaic, Gopher* server, *gopher* client, *FTP* server and *WHOIS++* server. The *Cyberstation* acts as the Domain Name Service (DNS) server, news server, mail server and proxy server for all member sites who require the service. This provides a major cost savings to the end users but is not a long term solution. "A very small district can get away with centralized servers and a medium sized district can get away with it for a while, but ultimately the services need to be at the school" [Lloyd, 94]. It is an excellent way for new administrators to learn how to manage network accounts. It is expected that a variety of low-cost server configurations will become available. As servers migrate into schools and districts hardware and software standardization will reduce administrative overhead. This is a good area for future implementation work.

G. WAN TOPOLOGY DESIGN

The PVC topology evolving from the decisions of the network design team is similar to Figure 6.7. Frames from member sites are transiting the Frame Relay cloud to the COE and then through the Frame Relay cloud again to the Internet. This simple design works well and has the advantage of placing the COE is in a position to filter traffic. It has the distinct disadvantage of creating a potential single point of failure (i.e. the COE server). An alternative design is allow access from the school to both the COE and the Internet provider directly.

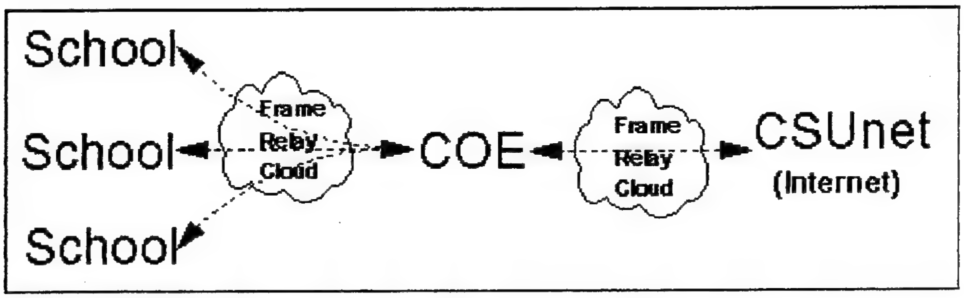


Figure 6.7 County Office of Education (COE)-centric WAN design with a potential single point of failure at the COE.

Figure 6.8 demonstrates a modified design that reduces the traffic navigating the Frame Relay cloud and eliminates the single point of failure. The loss of the COE serverwould not affect the school's ability to access the Internet, nor would the loss of CSUnet affect the ability of the sites to communicate with their respective COE's.

The network design team created a compromise of the two designs. The COEs determined that the ability of the COE to filter inappropriate traffic for the K-8 community was an fitting and necessary role. K-8 schools will not have direct Internet access PVCs. System availability was considered more vital than proper use censorship at the high school level, where dual PVCs will be implemented. The final PVC topology is presented in graphical form in Appendix I.

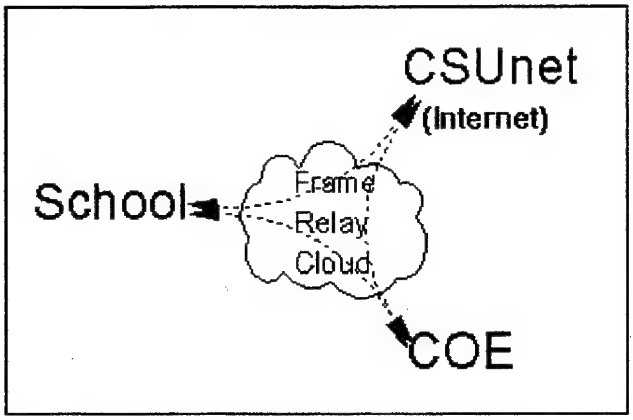


Figure 6.8 Multiple PVC WAN design.

Each PVC consists of two IP addresses which map both ends of a DLCI. The technique for accomplishing this is called "subnet masking" and is described in the next section. Figure 6.9 shows the map of DLCI 906 connecting Monterey High School's physical address of 205.155.36.0 with MCOE's physical address of 205.155.43.0. Recall that the DLCI number is issued from PacBell and is associated with a CIR. The sum of all CIRs is not allowed to exceed approximately 200% of the physical line capacity [Bellamy, 95]. Appendix J is PacBell's Monterey BayNet Frame Relay DLCI/CIR matrix.

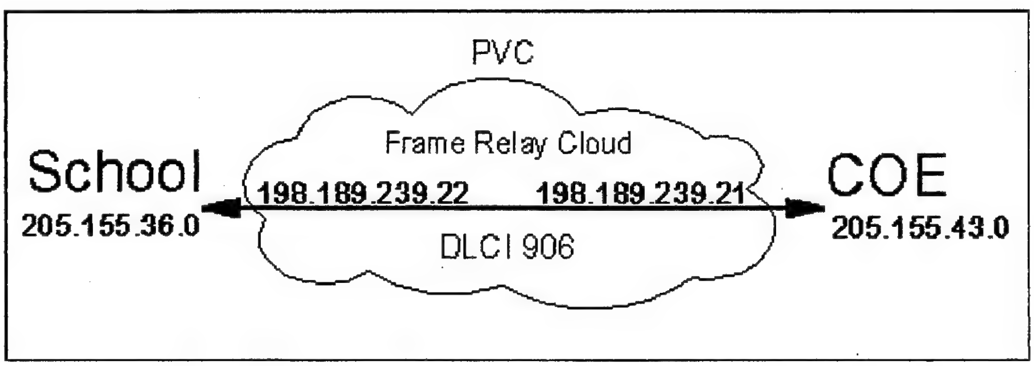


Figure 6.9 Example Data Link Control Identifier (DLCI) mapping.

H. DLCI SUBNET MASKING

IP addresses are written in dotted decimal format. 205.155.36.7 is the address for a single node at Monterey High. An IP address is 32 bits in length and composed of 4 segments. Each segment of an address space is 8 bits in length. In decimal notation each 8-bit segment equates to a number between 0 and 255. By convention the specific values 0 and 255 are reserved, leaving 1 through 254 available for use in addressing [Lynch, 93].

A Class C address is the block of 254 addresses available in an address of the format W.X.Y.0, where W, X and Y are the unique identifier segments to that LAN. Every Monterey BayNet site is issued a Class C block as their physical address space. Monterey High's Class C address is 205.155.36.Z, allowing them to assign up to 254 unique IP addresses to their nodes (205.155.36.1 through 205.155.36.254). Monterey BayNet convention assigns W.X.Y.1 to the site router, and W.X.Y.2 to the Internet server (if present). LAN address space subnetting is neither required nor desired. Monterey BayNet's Internet provider (CSUnet) has been expressly requested that sites not subnet the LAN class C address blocks assigned. Additional class C address blocks will be issued upon request if more that 254 nodes are required.

DLCI's are specific to Frame Relay WANs. DLCI's pair together two IP addresses to map the ends of the PVC. Rather than waste hundreds of Class C addresses a method was devised to subnet a single Class C address. 255 base 10 converted to base 2 binary is 11111111. Zero in binary is 00000000. In subnet masking the process used varies the final octet to derive multiple host-pairs. Monterey BayNet DLCIs use a subnet mask of 255.255.255.252. 252 in binary is 11111100. This convention tells computers that the first 6 bits of the final octet are the subnet address, and the final two bits are the unique host. Table 6.4 demonstrates how this creates 63 unique host-pairs within a single Class C address space, of which 61 are usable for DLCIs. Appendix I shows all Monterey BayNet DLCI assignments and the IP mapping of the DLCIs.

I. DOMAIN NAME SERVICE

Each site has a unique physical address issued from the block of Class C addresses provided by the Internet provider [Gerich, 93]. An alternative method of obtaining a block of addresses is to request them directly from InterNIC registration services. Appendix K provides the template for requesting IP address space from InterNIC.

People have a difficult time recalling numbers. 205.155.36.Z is not intuitively recognized as Monterey High School. Contrast 205.155.36.0 with a domain name of mhs.monterey.k12.ca.us. The casual observer can presume that it is a K-12 high school acronym from Monterey, California, United States. This system of linking physical addresses to names is known as domain name service [Postel, 94]. All K-12 schools are required to register under the US domain [Copper, 93]. RFC-1480 and RFC-1591 describe DNS registration and naming conventions. Monterey BayNet and the net design tiger team worked with the COEs to develop an acceptable DNS for member sites. The default name server for all schools is the COE *Cyberstation*. Appendix L is the DNS for Monterey BayNet. Appendix M is the InterNIC registration services DNS registration template.

J. ROUTING DECISIONS

The final planning event before connecting LANs to the WAN is the consideration of which *routing* protocol to use, and what *routed* protocols to allow. *Routed* protocols are protocols that are routed through a network. Internet Protocol (IP), *AppleTalk*, and *NetWare* (IPX) are some of the common routed protocols operating on LANs throughout Monterey BayNet. Monterey BayNet is initially allowing only IP traffic to be routed over the WAN. This decision increases security by removing the threat of LAN intrusion by outsiders. Hackers outside of Monterey BayNet can not easily access information from Monterey BayNet hosts unless that information is specifically contained on an Internet server. The decision to route IP only also significantly reduces the

administrative overhead of managing multiple routed protocols and eliminates many possible failure modes.

SUBNET	HOST	IP ADDRESS	DLCI	COMMENT
000000	00	198.189.239.0	*	* By convention neither host nor subnet can contain all zeros or all ones
000000	01	198.189.239.1	*	
000000	10	198.189.239.2	*	
000000	11	198.189.239.3	*	
000001	00	198.189.239.4	*	
000001	01	198.189.239.5	902	This is the first unique host address pair DLCI 902 links NPS with MCOE
000001	10	198.189.239.6	902	
000001	11	198.189.239.7	*	
000010	00	198.189.239.8	*	
000010	01	198.189.239.9	903	This is the second unique host address pair DLCI 903 links Seaside with MCOE
000010	10	198.189.239.10	903	
000010	11	198.189.239.11	*	
000011	00	198.189.239.12	*	
000011	01	198.189.239.13	904	This is the third unique host address pair DLCI 904 links MBTEC with MCOE
000011	10	198.189.239.14	904	
000011	11	198.189.239.15	*	***...continues thru 198.189.239.254***

Table 6.4. DLCI addressing with subnet mask 255.255.255.252.

The *routing* protocol is the set of rules that the router uses in forwarding traffic across the WAN. Three *routing* protocols were considered in detail: Routing Information Protocol (RIP), Interior Gateway Routing Protocol (IGRP) and Open Shortest Path First (OSPF) . To ensure interoperability across the WAN the Internet provider again played a large role in the final decision process.

1. Routing Information Protocol (RIP)

RIP maintains a set of routing tables in each router. The tables indicate the path to a destination host and the "distance" (i.e. number of intermediary routers between the two points) to that host. RIP maintains only the shortest route to a destination. As the "best" paths change the revised table is sent as an update message to neighboring routers. Each router receiving an update message revises its tables. On a limited scale network RIP is effective and easy to implement. As the network grows the tables become burdensome and update messages consume significantly greater bandwidth [Stallings, 94]. RIP is an old protocol and its use is considered detrimental by many Internet experts.

2. Interior Gateway Routing Protocol (IGRP)

IGRP is a distance vector interior-gateway protocol (IGP). IGPs use an Autonomous System number (AS) to identify members of a unique WAN. Distance vector routing protocols call for each router to send all or a portion of its routing table in a routing update message at regular intervals to each of its neighboring routers in the network [Stallings, 94]. As routing information proliferates through the network, routers can calculate distances to all nodes within the AS.

3. Open Shortest Path First (OSPF)

OSPF is a open standard link-state routing protocol [Moy, 94] based on the Shortest Path First (SPF) algorithm [Dijkstra, 59]. OSPF sends link-state advertisements (LSAs) to all other routers within the same AS. As OSPF routers accumulate link state information, they use the SPF algorithm to calculate the shortest path to each node [Stallings, 94].

4. Selection and Implications

OSPF was initially targeted as the routing protocol for Monterey BayNet because it can provide the most effective use of bandwidth. However, difficulty implementing OSPF on the *Cisco* routers during configuration training caused a reversal of policy.

> An earlier recommendation from CSUnet was to use OSPF within our network. However, the *Cisco* engineers found some ugly side-effects in *Cisco*'s implementation of OSPF and Frame Relay that would increase the complexity of the addressing in our network. CSUnet now recommends, with *Cisco*'s concurrence, that we use IGRP within the Monterey BayNet. [Taylor, 95]

Two final configuration parameters were established. The Logical Management Interface (LMI) defines the protocol for communication between a Frame Relay switch and a specific router interface. Monterey BayNet adopted the use of ANSI Logical Management Interface, standard T1.617 Annex D.

The *Cisco* implementation of IGRP requires the use of an AS number [*Cisco*, 95]. "Registering for an Autonomous System Number implies that you plan to implement one or more gateways and use them to connect networks in the Internet." [InterNIC, 94] A gateway is a method of connecting other WANs via the Monterey BayNet host [Sprague, 93]. Monterey BayNet does not currently operate any WAN gateways. To fulfill the requirement for an AS in the *Cisco* routers Monterey BayNet arbitrarily assigned the AS number 10 in Santa Cruz, and 11 in Monterey. Using an unregistered AS number will not cause problems since AS numbers, unlike their IP number counterparts, are transparent to end systems. Excerpts from the InterNIC AS registration template are provided for reference in Appendix N. The current version of the template is maintained at *ftp://rs.internic.net/templates/asn-template.txt*.

K. WAN DESIGN PROCESS SUMMARY

To the non-technical observer the task of designing a WAN seems overwhelming. Monterey BayNet was successfully designed by the cooperative pooling of knowledge, experience and needs. Few members in the network design team had extensive network backgrounds. None had the breadth of knowledge needed to answer all questions, nor was any such person ever located. All had the desire and drive to ask all the right questions and search for the right answers. This team process has been a critical component in successfully identifying and overcoming the many hurdles involved in designing and implementing LANs and WANs .

Following the model outlined at the start of this chapter (Figure 6.1) the network design team selected Frame Relay bearer service as its communications mode. It received multiple bids for Internet access and selected CSUnet as the Internet provider. Working in cooperation with CSUnet and PacBell the network design team selected the WAN hardware and initiated group purchases to maximize savings.

With the above decisions the creation of a model topology was relatively simple. The topology models demonstrated strengths and weaknesses which were evaluated and capitalized upon. IP addresses were assigned to PacBell's DLCIs based upon the topology created, and a workable CIR matrix was agreed upon with PacBell. Unique site IP addresses were assigned and linked to domain names registered within the US domain name system. Finally the routing and routed protocols were evaluated and agreed upon, creating the need for additional registration of two autonomous system numbers.

Monterey BayNet as designed above has created a simple-to-implement, reliable regional network. There has been no opportunity yet to evaluate the design following implementation. To date it has met all expectations. Undoubtedly there are bound to be numerous nuances which were not considered or not anticipated. Traffic patterns will be analyzed to verify the design topology. At some point the inter-LATA issue may have to be re-addressed. Much of the work of network management and administration has only just begun, even as expansion plans are surfacing. Persistence and perseverance helped us

find technical solutions for all technical problems and people solutions for all people problems. The same collaborative spirit which designed Monterey BayNet will continue to shape its evolution.

VII. IMPLEMENTATION RESULTS

A. IMPLEMENTATION INTRODUCTION

On March 24, 1995 Seaside High School became the first Monterey BayNet site on-line. To date 25 of 43 sites are on-line and installation efforts continue. May 12, 1995 marked the next milestone with the first point-to-point videoconference between two sites using *CU-SeeMe* [Herbst, 95][Cogger, 95].

The implementation phase began concurrently with the design phases. Configuration "tiger" teams from Cabrillo College and the Naval Postgraduate School began conducting site inspections in November 1994 [Bigelow, 94]. The net design team recognized that the end users understanding of their role was critical to success. Implementation has been conducted in three steps.

1) Initial site inspection with PacBell and configuration team.

2) Informal follow-up of on-site technical, timing and procurement issues.

3) PacBell Frame Relay installation and tiger team configuration.

This chapter will highlight the configuration team's implementation process and the issues faced at the site and WAN management levels.

B. INITIAL SITE INSPECTIONS

Initial site inspections called "walk-throughs" proved to be of critical importance in the implementation of Monterey BayNet. The format was a scheduled meeting between site personnel, PacBell Frame Relay installers, and configuration team personnel. In most cases this was the first opportunity for end users to ask technical questions and begin to understand their roles and responsibilities.

The first task in the walk-through process is for PacBell to establish the location of the MPOE and verify that sufficient lines are present to the MPOE for Frame Relay installation. California schools are generally over twenty years old and the MPOE is not

always obvious. In one case it was in an building no longer used by the school, on the other side of the football field. If the MPOE is not in a position close to where router will be installed, it is recommended that PacBell be consulted on establishing a secondary MPOE or extending the NIU to the router location. The location where the router and CSU/DSU will be installed will require sufficient space for either wall mounting of the devices, or installation of a shelf where the devices can sit. The *Cisco* routers come with brackets which allow them to be easily mounted flat on the wall. If a shelf is used ensure that a strap is attached to secure the devices to the shelf. The location will also a require 110VAC surge protected power supply for both the router and CSU/DSU.

The next task of the walk-through inspection is discussion of the LAN design guidelines contained in Chapter V. The goal is not to design a LAN for the end user, but to enable the end user to consider LAN design options and to make an educated business decision at a later date. An equipment recommendation list is critical at this point to assist end users in understanding the financial impact of design options. The most frequently asked question during a walk-through is "how much does it cost." Of greater importance is communicating the need to invest up-front in an infrastructure which will meet today's needs while remaining scalable in the future.

A walk-through situation to avoid is one where a LAN already exists, and the maintainer of that LAN is not present at the brief. In the K-12 educational sector it is not unusual for technology to be viewed as a display tool for casual use, rather than as an information resource which must be managed. In several walk-throughs end users expected the configuration team to have perfect knowledge of their network from the examination of a single terminal. Insist on the presence of the network administrator or consultant who maintains the system.

The final task of the walk-through is to ensure that the end users understand the installation schedule and what roles PacBell, the configuration team and end user play. It must be clearly understood that PacBell will not install past the MPOE without prior agreement, and that PacBell's responsibility ends at the NIU (or at the RJ-48 if installed by PacBell). The end user is responsible for procurement of all equipment after the NIU,

especially the installation of all LAN hardware and wiring (if required). The configuration team's role is to assist in the configuration of WAN devices and software applications.

C. WAN EQUIPMENT INSTALLATION AND CONFIGURATION

The amount of information presented at the walk-through is substantial. On average the discussions lasted between two and three hours. Many requests for further information and clarification were received by the COEs and the configuration teams. In February a Frame Relay service "roll-out" schedule (included in the CIR matrix, Appendix J) was created by PacBell and the COEs. The roll-out was based upon the results of the walk-throughs completed and end-user requests. It is interesting that certain sites were already emerging as leaders in technology implementation. Without exception these sites had one or more champions who were willing to invest personal time integrating the technology successfully into their school [Gwinn, 94].

Figure 7.1 is a configuration team installation checklist. The checklist shows a logical progression through the configuration process. Many of the tasks can be performed simultaneously with multiple installers. The key learning points for the end user are the troubleshooting methods and corrective actions in the case of a suspected WAN error, and the functionality of the software applications installed on the computers. Training issues will be discussed in greater detail later in this chapter.

During the configuration of the *Cisco* routers is was discovered that *Cisco* operating system version 10.2 or greater was required in order to implement the sub-interfaces for multiple point-to-point PVCs. Some of the routers were shipped with version 10.0 and had to be updated. The procedure for updating is contained in the *Cisco* support documentation chapter titled "*Upgrading Run-From-Flash Software Images in the Cisco 2500*" [Cisco, 95].

- Configure TSU/DSU and router (Appendix G, H). Verify proper operation prior to installation.
- Verify PacBell and LAN installation complete prior to installation.
- Install router, TSU/DSU, and RJ-48 (if necessary - Appendix F). Verify adequate ventilation and power supply are available.
- Verify connectivity from the router through the frame relay cloud to another router.
- Install proper transceiver (10BASE-T or 10BASE2) and connect LAN to router.
- Instruct end users in the meaning of the router, transceiver, and CSU/DSU indication lights. Discuss corrective actions and points of contact.
- Verify all router and TSU/DSU documentation is presented to the end user.
- Instruct end users in Class C IP address management. Assist them in starting a log of address assignments.
- Install TCP packet drivers at each LAN terminal (Appendix O, P).
- Install applications on each terminal. Explain *Eudora* mail program setup. Explain the cautions associated with CU-SeeMe use in Monterey BayNet.
- Test and demonstrate applications.

Figure 7.1 Configuration Team Installation Checklist.

With the TSU (or DSU for 56 Kbps sites) and router configured and energized but not connected, the TSU will show green "PWR", "TD" and "RD" LEDs as well as a red "ALM" indication showing that Frame Relay service has been interrupted. Connecting the TSU "Network" port to the RJ-48 with the provided silver satin cable should clear the alarm indication. If this is not the case then there is a problem in the TSU, a wiring problem exists, or the Frame Relay signal has been lost. Troubleshoot in that order. Verify the TSU operation with a self-test. Verify the silver satin cable connectivity end-to-end on each pin. Verify RJ-48 wiring as per Appendix F. Finally contact the PacBell Network Operations Center at 1-800-870-9007. Have the circuit identification (written on the PacBell NIU) and a call-back telephone number ready.

The router is connected to the TSU with the V.35 cable described in Chapter VI. This final connection should illuminate the remaining two LEDs "RTS" and "CTS". If this is not the case then there is a problem with either the router configuration or the V.35 cable. Troubleshoot them in that order. With all five of the green LEDs illuminated, no alarms,

the router can be used to verify WAN connectivity with a "ping" check to the COE (205.155.8.1 and 205.155.43.1 in Santa Cruz and Monterey respectively).

At this point the WAN connection is completed. Ensure all documentation is consolidated and presented to the site's network administrator. Finally verify the LAN connection to the transceiver on router's Ethernet port. The remainder of the configuration will be conducted at each individual computer which desires access to the WAN.

D. LAN CONFIGURATION AND APPLICATION INSTALLATION

Each site has a class C address space assigned. It is the responsibility of the site network administrator to manage this block of addresses. Monterey BayNet convention assigns 205.155.Y.1 to the router, 205.155.Y.2 is reserved for the site's (future) Web server. The remainder of the addresses (205.155.Y.3 through 205.155.Y.254) will be assigned to devices sequentially by the network administrator. Maintain an accurate log of address assignments. Label each device with the address to avoid confusion.

MacTCP and *Trumpet Winsock* are the respective software packet drivers for *Macintosh* and *Windows* platforms. Each device that will have WAN access will need a packet driver installed and manually configured with the device's assigned IP address. Appendices O and P describe the packet driver installation and configuration procedure for the respective platforms.

1. Configuration of Computers in the LAN

The application software is installed on each computer in a folder (directory) titled Internet. Most of the applications are compressed and require expansion. On *Macintosh* platforms install the self-extracting program *Stuffit-Expander* from the *Macintosh* disk 1 of 5 first. All other *Macintosh* applications can be installed by dropping them on top of the expander icon. The *Windows* extraction program is *WinZip*. *WinZip* is a self-extracting executable file. Copy *WinZip* to a temporary file in the file manager before executing, then

follow the installation prompts as they appear. The remainder of the *Windows* applications can be expanded by double-clicking on the files with .zip extensions. Some *Windows* applications may require the execution of setup files or modification of the path in the *autoexec.bat* file. Refer to the application's supporting documentation for specific installation instructions.

2. Configuration of a Diskless LAN

The software suite selected for Monterey BayNet was designed to be as inexpensive as practical while maintaining functionality. As a result the software is not networkable, i.e. it is for single users not multiple shared users. This implies that the application software must reside on each individual platform in order to give that platform the complete functionality of the associated application. If the software is called from a file server then only one user will be able to access the application at a given time.

El Sausel Middle School in Salinas California operates a (mostly) diskless LAN. Each computer is equipped with a boot ROM or boots from a floppy disk [Alvarez, 95]. Users login to the *Novell* file server to load *Windows* and the Internet applications. Configuration of terminals in a diskless LAN is nontrivial and beyond the scope of the configuration team's experience. El Sausel employed the services of a Novell CNE to configure their LAN. Unfortunately, because the software suite is not networkable, only one user can access each Internet application at a given time. This is not a side effect of a poorly designed network. Application servers are desirable in LANs. This is a function of the low-cost shareware software suite. Networkable software with the same functionality or better is available for a substantial fee. Other newer computers on the same LAN do have hard drives and are enjoying full Internet functionality.

3. Configuring *Eudora* Mail Program in a Multi-User Environment

Eudora is the only user-specific software application in the shareware suite. It is necessary to set *Eudora* so that the personal configuration settings of each user are drawn from a personal disk. This prevents mail from being sent out under a false user name. In *Windows* this is accomplished by the configuration outlined in Figure 7.2. The *Macintosh* configuration of *Eudora* for multi-users is outlined in Figure 7.3.

- Create a new directory called c:\eudora and copy weudora.exe into it.
- Create a directory called c:\eudora\temp
- Add the following environment variable to your autoexec.bat file:
  `Set tmp=c:\eudora\temp`
- Add Eudora as a new program item to a the Internet Program Group.
- Modify the Eudora program Item as follows:

Description:	`weudora`
Command Line:	`c:\eudora\weudora.exe a:\`
Working Directory:	`a:\`

Figure 7.2 Multi-user *Eudora* Configuration Under *Windows* [Beckley, 94].

- Install Eudora on the Macintosh hard drive with no configuration parameters.
- Store each user's Eudora Settings File on a floppy disk.

Figure 7.3 Multi-user *Eudora* Configuration on a *Macintosh* [Lapp, 95].

In both cases a unique diskette for each user will be required. To operate in the *Windows* environment the user will insert the disk into drive "A:" and then double click on the *Eudora* icon in the Internet group. In the *Macintosh* case the user will click on the *Eudora* icon within his disk. In both cases this will start *Eudora* with the individual's unique configuration settings.

4. Responsible use of *CU-SeeMe* in Monterey BayNet

CU-SeeMe is an interesting and powerful point-to-point videoconferencing application [Cogger, 95]. Site administrators need to be advised that irresponsible *CU-SeeMe* usage can cause adverse effects in LAN and WAN response. *CU-SeeMe* requires large bandwidth and creates a continuous stream of data through the Frame Relay cloud. Recall that Frame Relay technology is based upon the transmission of variable length Frames over virtual circuits. Imposing a continuous stream of data over the Frame Relay circuitry effectively removes that amount of bandwidth from being shared with other clients.

Read the accompanying documentation provided with *CU-SeeMe* before using the application. In particular read and comply with the recommendations on bandwidth adjustment. Do not transmit at greater then 80Kbps on the WAN. The best method of controlling *CU-SeeMe* access is to limit *CU-SeeMe* installation to supervised machines. 56 Kbps Monterey BayNet sites should limit *CU-SeeMe* access to a single platform. The bottom line: *CU-SeeMe* can clobber the network so use it sparingly and carefully.

E. SUPPORT

Monterey BayNet is a fully operational network providing services today which are being used in participating schools throughout the region. The initial success has been largely due to the collective efforts of the I^3LA net design team in planning, implementing and training. In order for the technology to be fully integrated into the classroom environment it must be a reliable and dependable product. Educators need to understand the basics of the technology, the use of the applications, and know that the product will be available when they require it. This implies that a supporting structure of educator training and WAN management must be in place. These issues are currently being examined by the I^3LA and Monterey BayNet. The remainder of this chapter will highlight the critical areas of concern for Monterey BayNet future sustainability and growth.

1. Formal End User Training

A model for training educators in the use of the application software must be formalized and accessible. The I^3LA white paper recommended the implementation of a "train the trainer" approach [Brutzman, 94], with Tier I and II sites being responsible for the training of Tier II and III sites. This method has achieved superior results in conveying specific material to limited groups on an ad hoc basis. As a final solution the "train the trainer" method does not scale to the scope of the target audience now attempting to access Monterey BayNet. Clearly ad hoc training is valued and appreciated, but a formal systematic approach which is designed within the bounds of the current education system is required in order to reach all educators. The I^3LA and Monterey BayNet can assist in the development of the content for user training, but formalization must come from the County Offices of Education. This issue closely parallels one responsibility of a Network Information Center (NIC) yet deserves immediate attention in the absence of an official NIC.

2. Network Information Center (NIC) Justification

A Network Information Center (NIC) is the group or organization which is primarily responsible for user services. This is not to be confused with connectivity. The NIC is not responsible for building or maintaining network connectivity. User services can generally be grouped into "help-desk" functions such as establishing new user accounts, answering questions about application software, training users, developing policy and directing users toward available resources.

By default the county offices of education are performing the NIC function within Monterey BayNet because they are the only organization which can currently establish and maintain user accounts. The *Lloyd Cyberstation* used in Monterey BayNet provides a GUI which allows non-technical personnel to maintain accounts with relative ease. The larger

issue is the manning of the NIC with personnel who able to assist users with their questions and have the authority to develop and carry out training events.

3. Troubleshooting Methodology

The site network administrators require training in network administration particularly in troubleshooting methodology. Non-technical site administrators with questions are currently at the mercy of volunteer schedules and a single WAN administrator in each county office of education. A clear path for troubleshooting, system responsibility, and points-of-contact need to exist and be understood by local network administrators.

The majority of network errors encountered throughout the implementation phase have been unrelated to WAN connectivity. Training local network administrators so that they can recognize that WAN connectivity exists (or doesn't) would greatly reduce the burden on the WAN administrators. The final goal should be local administrators who feel comfortable that they can isolate a problem to either a local node, WAN access, or access beyond Monterey BayNet. In each case the local network administrator needs to understand who the responsible agent is for correcting the error and how to contact them. This issue closely parallels one responsibility of a Network Operations Center (NOC) yet deserves specific attention in the absence of an official NOC.

4. Network Operation Center (NOC) Justification

A Network Operations Center (NOC) is the group or organization responsible for the day-to-day maintenance of the WAN. This is accomplished through the monitoring of online statistics including traffic patterns, congestion reports and data from SNMP clients. Many software packages exist which aid in the recognition of network problem areas. Unfortunately resolution of these problems must be accomplished manually and often requires significant technical expertise. Nevertheless many large and small organizations do

not have a formalized NOC. All organizations have a person or persons which perform that role, with or without the aid of automated monitoring devices.

The Monterey BayNet NOC function is currently being carried out by the collective members of the I³LA network design team in cooperation with the county office of education WAN administrators. This approach is not sustainable. The responsibility for communication with the Internet provider, Pacific Bell, contractors, and numerous manufactures has too many legal ramifications to remain in the domain of volunteers, regardless of how qualified they may be. By default the role of the NOC falls to the county offices of education. This function can also be easily outsourced to any competent service provider with the required facilities and staff. The I³LA is working with Monterey BayNet to resolve NOC transition requirements.

F. IMPLEMENTATION SUMMARY

The Monterey BayNet WAN is being successfully implemented in a three phase process which includes initial site inspection, informal follow-up, and installation. To date 25 of the 43 CalREN sites are online and installation efforts continue. Monterey BayNet is providing all of the services specified in the end user requirements. The technical problems of implementation are rapidly giving way to human ones. The need for consistent and available training on the use of the software applications provided, as well as the need for a readily available information and assistance center are the driving factors of the next phase of the implementation. The implications of delaying the implementation of a full scale NIC and NOC could be cause for concern.

Areas for continuing research include NIC and NOC design and deployment, policy development in the K-12 Internet environment and models of technology integration in the classroom. In the area of human resource management further research could study the reaction of technology intervention in the Monterey BayNet education system. New lines of communication are being formed by technology in education and the long term result may be nothing short of full scale restructuring of the education model.

VIII. APPLICABILITY TO DEPARTMENT OF THE NAVY (DoN) SHORE COMMANDS

A. INTRODUCTION

The Monterey BayNet project has numerous learning points that transition directly from the K-12 environment into wide area networking efforts within Department of the Navy shore commands. The Monterey BayNet effort focused on a population of end users with minimal networking skill levels sparsely distributed over a large geographic region. Using commercial off the shelf (COTS) products and requiring no new studies, this group of volunteers implemented a WAN capable of high-speed communication of voice, data and images.

B. REQUIREMENTS DEFINITION

Monterey BayNet spent considerable time attempting to define the baseline system requirements for end users. This first step in the systems development life cycle is critical in that it forms the foundation for network design and applications development [Whitten, 89]. The process included a thorough review of available K-12 networking documentation, applicable grant documentation and most importantly end user interview and observation. The requirements which were defined in this process played a leading role in the subsequent development of the software applications, minimum recommended personal computer hardware, telecommunications service selection, and implementation methodology.

Understandably defining end user requirements is much like trying to paint a moving train, but the time spent understanding the scope of the problem and the expected outcomes clearly enabled the net design team to focus its efforts on a shared vision. Further refinement of the end user requirements will be easier now that there are tools in place to measure and evaluate.

C. DESIGNING FOR GROWTH

The network design team's focus on scalability in every aspect of design is critical to the long term success of the network. In LAN design recommendations were focused toward the implementation of 10BASE-T designs to allow migration paths for further network expansion. The physical infrastructure recommended the installation of upgraded UTP, where new wire was required, to allow future expansion to 100BASE-T. In WAN design the recommended entry level was 128 Kbps to allow future increases in frame rate without the need to invest in additional hardware. The one fact that can be relied upon is that networks will grow in size and applications will require increasingly higher data transfer rates. Monterey BayNet and the Monterey BayNet sites have the ability to expand in both directions.

D. STANDARDIZATION

Early standardization of hardware increased the manageability of the network. The configuration team was required to learn only a few systems in order to effectively connect sites. Standardization also assured interoperability within the WAN. The economies of scale generated by group purchase techniques generated cost savings as well as manufacturer attention and support for the project.

E. COST REDUCTION

The Monterey BayNet project achieved dramatic results in an extremely cost conscious environment. Similar methods applied in DoN networking projects may yield the same result. No new studies were required or requested in the design and implementation of the network. All solutions were COTS products and all technology used was proven in industry prior to the network design team's consideration. Savings at the local level were promoted through the effective evaluation of existing infrastructure.

Many schools were able to reuse excess capacity wiring for LAN installation. The use of on-site personnel to run new cable installations greatly reduced cost to schools.

F. MAINTAINABILITY

Simple Network Management Protocol (SNMP) clients and WAN management applications are valuable tools to assist personnel in the management of a WAN. These tools are not a substitute for knowledgeable technicians who can address problems as they are identified. The question to be considered in planning NIC and NOC functions is not a technical question as much as it is a human one. NIC and NOC staffing and a plan on how to address technical and human issues are much more valuable than a software suite which allows an operator to pinpoint a problem without the means to correct it.

G. SUMMARY

Monterey BayNet serves as a practical reminder that networking solutions must be oriented to the end user and not the technology. Wide-area network connectivity can be achieved in a manner which optimizes economy and design. Infrastructure design and installation can be accomplished with nontechnical personnel at great savings. The management and maintenance of a network is simplified though standardization. Finally maintenance is a personnel problem, not a technical problem. Technical issues have technical solutions, whereas people issues require people solutions.

IX. CONCLUSIONS

Monterey BayNet works!

Students and educators began collaborating via the Monterey BayNet on March 24th 1995. The network is obviously still in its infancy and there are a number of personnel issues to resolve, but the end user requirements which were defined in Chapter IV are being met and exceeded. Monterey BayNet provides an information infrastructure that enables such a fundamental shift in the educational paradigm that it may take years to fully resolve the issues of integration within the educational system and the impact on teaching and learning. The reactions of the students and parents of the Monterey Academy of Oceanographic Sciences (MAOS) clearly indicate that student and parent interest is enormous. Students and parents alike were captivated by the concept of being able to share their research with the world. The end product at MAOS was a dedicated student effort to create a home page which expressed their research project results as well as their enthusiasm. The URL for MAOS is *http://205.155.54.2/maos/home.html* [Pool, 95].

The key to Monterey BayNet success has been the dedication of the individuals involved with the collaborative effort. A single expert does not exist. Interested educators, researchers and technicians have doggedly pursued a common vision to fruition. The fact that Monterey BayNet has arrived at this stage after little more than one year is nothing short of remarkable and speaks volumes about the strength of the collaborative effort in Monterey Bay.

A second key contributor to success has been the continual focus on the end user. This author finds it remarkable that some sites have networked every room of their entire campus without outside assistance. The technology transfer discussed in Chapter V combined with the information presented in the appendices is literally all of the guidance used in most cases throughout Monterey BayNet. Student volunteers from the Naval Postgraduate School and Cabrillo College assisted in the technology transfer process by

conducting walk-thru inspections, usually learning more from answering the end user questions than the end user did.

The final linchpin was the terrific assistance provide by *Pacific Bell*, *Cisco*, and *Lloyd Internetworking*. The final implementation of the WAN could not have been coordinated better or benefitted from stronger partners. The relationships fostered with these corporations have greatly assisted the members of the I^{3}LA net design team to understand the technical issues as they developed.

Collaboration implies cooperation, a give and take relationship which is founded on trust and vision. While at times the speed of the consortia seemed appallingly slow, it is equally true that when a decision is finally reached it has been completely examined, often repeatedly. This is beneficial to the final product, provided that the central focus does not waver. Monterey BayNet's measure of success has continually remained the number of students and teachers online. This focus has been crucial in achieving success to date.

Further research continues within the I^{3}LA net design team. The next phase of Monterey BayNet development must veer radically from the technical issues to address the people and policy issues. Training, user support, manning of a network information center (NIC), and providing a plan for technical support (NOC functions) are all issues which must be resolved for Monterey BayNet to be sustainable after the CalREN grant expires. A key ingredient again must be end user "buy in". This author feels strongly that the best mode of accelerating educator acceptance of technology is to grant them access to the same applications from home. Dial-in service limited to educators can allow the educators the leisure of learning "what" and "how" from home, creating a "Tier IV" of access. Limiting that access to educators is an important policy question. Monterey BayNet may not want to place themselves in a position where they are competing with local Internet providers for the home dial-in market, namely parents. On the other hand, providing some additional access might support financial sustainability.

In summary the processes used to develop Monterey BayNet all focused on meeting the requirements of the end user today and in the future. Design efforts stressed upward bandwidth transition paths and well as LAN expansion paths. The WAN stressed equipment standardization to assure interoperability and management sanity. SNMP was recommended to allow future growth toward remote WAN monitoring to assist end users. Every facet reflects end user ease of use, manageability, and scalability.

APPENDIX A. MACINTOSH SOFTWARE DOWNLOAD SITES

The following is a list of the Monterey BayNet recommended software for *Macintosh* platforms. This list reflects the latest versions of software as of this writing. Pointers to download sites listed can be found at **http://monterey.k12.ca.us/ macsoft.html**. This list is maintained by the Monterey BayNet system administrator and will reflect updates as they are implemented within Monterey BayNet.

Not all of the software is free. Review the copyright of every piece of software that is being installed. It is the responsibility of the system administrator to ensure compliance with all license and copyright requirements.

File extensions (.sit, .sea, .bin and .hqx) are used to indicate what format the file has been stored in. The .hqx (BinHexed) extension is normal and will be transparent to Macintosh users. The same holds true for files with the .bin (Binary) extension. All files with the extension .sit (Stuff-It) will have to be extracted with the *StuffIt Expander* or similar application. The extension .sea (Self Extracting Archive) indicates that the file will automatically expand itself. Each application has a compressed file size listed. Total system disk space required for a complete software installation is approximately 45 megabytes (MB).

MacTCP PROPRIETARY
MacTCP is the software which enables TCP/IP connectivity. *MacTCP* software comes bundled with the system 7.5 operating system. All older operating systems require a licensed copy of *MacTCP*. The easiest way to obtain *MacTCP* is through the purchase of *The Internet Starter Kit for the Macintosh* (currently $29.95) at many bookstores [Engst, 94].

Netscape - Version 1.1N - *Windows* version available. FREE EDUCATIONAL USE
A graphical WWW browser.
ftp://ftp.mcom.com./netscape/mac/netscape_1.1N.hqx
1625 KB

Eudora - Version 2.1.1 - *Windows* version available. FREEWARE
Send and receive electronic mail.
ftp://ftp.qualcomm.com/quest/mac/eudora/1.5/eudora152fat.hqx
649 KB

NewsWatcher - Version 20b27 FREEWARE
A news reader. Note that news groups must be made available from the Internet provider.
ftp://ftp.acns.nwu.edu/pub/newswatcher/newswatcher-20b27.sea.hqx
625 KB

Fetch - Version 2.1.2 FREEWARE
A File Transfer Protocol (FTP) application for the *Macintosh*.
file://ftp.dartmouth.edu/pub/mac/Fetch_2.1.2.sit.hqx
363 KB

Anarchie - Version 1.4 FREEWARE
An FTP and Archie client. Archie is a method of searching FTP sites for information.
ftp://boombox.micro.umn.edu/pub/gopher/Macintosh-TurboGopher/helper-applications/Anarchie-140.sit.hqx
490 KB

Telnet - Version 2.6 - *Windows* version available. FREEWARE
Enable virtual terminal access to remote hosts.
file://ftp.ncsa.uiuc.edu/Mac/Telnet/Telnet2.6.sit.hqx
167 KB

TurboGopher - Version 2.0b7 - *Windows* version available. FREEWARE
A Gopher client for the *Macintosh*. Enables the download of files from Gopher servers.
ftp://boombox.micro.umn.edu/pub/gopher/Macintosh-TurboGopher/TurboGopher2.0.sea.hqx
316 KB

GifConverter SHAREWARE $40
Graphic image viewer and processor. Reads and writes the following graphics file formats: GIF, MacPaint, PICT, RIFF, RLE, Thunderscan, Startup Screen, TIFF and JPEG.
file://ftp.ncsa.uiuc.edu/Mac/Mosaic/Helpers/gif-converter-237.hqx
474 KB

JPEGView - Version 3.3.1 POSTCARDWARE
Graphic image viewer and processor. Reads and writes the following graphics file formats: JPEG, JFIF, GIF, PICT, Baseline and LZW-compressed TIFF, Windows BMP, Startup Screen, and MacPaint.
file://ftp.ncsa.uiuc.edu/Mac/Mosaic/Helpers/jpeg-view-331.hqx
769 KB

SoundMachine FREEWARE
Audio file player for SND/AU and AIFF/AIFC formats.
file://ftp.ncsa.uiuc.edu/Mac/Mosaic/Helpers/sound-machine-21.hqx
74 KB

Sparkle - Version 231 FREEWARE
MPEG and QuickTime movie viewer.
file://ftp.ncsa.uiuc.edu/Mac/Mosaic/Helpers/sparkle-231.hqx
1109 KB

SimplePlayer FREEWARE
A quicktime movie viewer
file://ftp.ncsa.uiuc.edu/Mac/Mosaic/Helpers/fast-player-110.hqx
13 KB

StuffIt Expander - Version 3.5.2 FREEWARE
Create compressed archives and decompress common *Macintosh* archived formats.
file://ftp.ncsa.uiuc.edu/Mac/Mosaic/Helpers/stuffit-expander-352.hqx
186 KB

DropStuff - Version 3.5.2 SHAREWARE $30
Enhanced version of *Stuffit Expander*. Create compressed archives and decompress archived formats including ZIP (.zip) and ARC (.arc) archives; AppleLink (.pkg) packages; gzip (.gz), Unix Compress (.Z), UUencoded (.uu), and StuffIt files (.sit).
file://ftp.ncsa.uiuc.edu/Mac/Mosaic/Helpers/drop-stuff-with-ee-352.hqx
521 KB

NCSA Collage - Version 1.2 - *Windows* version available. FREEWARE
A shared whiteboard application.
file://ftp.ncsa.uiuc.edu/Mac/Collage/Collage1.2/Collage1.2.sit.hqx
661 KB

BBEdit Lite - Version 3.0 FREEWARE
A high performance text editor.
file://ftp.ncsa.uiuc.edu/Mac/Mosaic/Helpers/bbedit-lite-30.hqx
392 KB

Bbedit-html-extension FREEWARE
Add-on extensions to BBEdit Lite which enable use as an HTML editor.
file://ftp.ncsa.uiuc.edu/Mac/Mosaic/Helpers/bbedit-html-b8.hqx
78 KB

CU-SeeMe - *Windows* version available. FREEWARE
Point-to-point videoconferencing.
ftp://CU-SeeMe.cornell.edu/pub/CU-SeeMe/Mac.CU-SeeMe0.80b2/CU-SeeMe.68k0.80b 2.bin
224 KB

Disinfectant - Version 3.5 FREEWARE
A program designed to detect and remove all known Macintosh viruses.
ftp://ftp.acns.nwu.edu/pub/disinfectant/disinfectant36.sea.hqx
232 KB

MacTCP Watcher - Version 1.12 FREEWARE
Application which displays IP and DNS information. Network testing.
ftp://redback.cs.uwa.edu.au/Others/PeterLewis/MacTCPWatcher-112.sit
79 KB

BLUE SKIES - Version 1.1 FREEWARE
Interactive weather information.
gopher://groundhog.sprl.umich.edu/11/Software/Blue-Skies_v1.1.sea.hqx
251 KB

MacWeather - Version 2.0.4 FREEWARE
Current weather information and forecasts.
ftp://cirrus.sprl.umich.edu/pub/Other_Software/Weather_Software/macweather2.04.hqx
116 KB

Adobe Acrobat - *Windows* version available. FREEWARE
A Portable Document Format (.PDF) file viewer.
ftp://boombox.micro.umn.edu/pub/gopher/Macintosh-TurboGopher/helper-applications/AcrobatReader/AcrobatReader2.0.1.hqx
2919 KB

GhostScript - *Windows* version available. FREEWARE
A *PostScript* (.PS) file viewer.
ftp://ftp.cs.wisc.edu/pub/ghost/aladdin/mac/

714	Kbps	*macgs-v1.0-files.sit*	- *GhostScript* files and documentation
438	Kbps	*macgs-v1.0-68k.sit*	- the application compiled for 68020 or better
2782	Kbps	*macgs-v1.0-fonts.sit*	- the standard *GhostScript* 3.0 fonts
17	Kbps	*manual.txt*	- the manual as unformatted text
1	Kbps	*readme.txt*	- instructions!

InterSLIP FREEWARE
Serial Line Internet Protocol (SLIP) makes TCP/IP communication possible via modem.
http://www.utah.edu/HTML_Docs/InterSLIP/InterSLIP.html
267 KB

MacPPP FREEWARE
Point-to-Point Protocol (PPP) makes TCP/IP possible communication via modem.
MacPPP is bundled with *MacTCP* when you purchase *The Internet Starter Kit* [Engst, 94].
ftp://ftp.merit.edu/internet.tools/ppp/mac/macppp2.0.1.hqx
75 KB

APPENDIX B. WINDOWS SOFTWARE DOWNLOAD SITES

The following is a list of the Monterey BayNet recommended software for *Windows* platforms. This list reflects the latest versions of software as of this writing. Pointers to download sites listed can be found at **http://monterey.k12.ca.us/ ibmsoft.html**. This list is maintained by the Monterey BayNet system administrator and will reflect updates as they are implemented within Monterey BayNet.

Not all of the software is free. Review the copyright of every piece of software that is being installed. It is the responsibility of the system administrator to ensure compliance with all license and copyright requirements.

File extensions (.zip) are used to indicate what format the file has been stored in. All files with the .zip (PKWare compression) extension will have to be extracted with the *WinZip* application. Each application has a compressed file size listed. Total system disk space required for a complete software installation is approximately 45 Megabytes (MB).

Trumpet Winsock Version 2.0 — SHAREWARE $25
The software which enables TCP/IP connectivity.
ftp.cica.indiana.edu/ftp/pub/pc/win3/winsock/twsk20b.zip
179 KB

Netscape - Version 1.1N - *Macintosh* version available. — FREE EDUCATIONAL USE
A graphical WWW browser.
ftp://ftp.mcom.com/netscape/windows/ns16-100.exe
706 KB

Eudora - Version 1.4.3 - *Macintosh* version available. — POSTCARDWARE
Send and receive electronic mail.
ftp.cica.indiana.edu/ftp/pub/pc/win3/winsock/eudor143.exe
303 KB

WinVN NNTP newsreader — FREEWARE
A news reader. Note that news groups must be made available by the Internet provider.
ftp.cica.indiana.edu/ftp/pub/pc/win3/winsock/winvn926.zip
176 KB

FTP - Version 94.03.25 — FREEWARE
A File Transfer Protocol (FTP) application that enables the download (and upload) of files from FTP servers.
ftp://ftp.csusm.edu/cwis/winworld/winsock/ws_ftp.zip
69 KB

Archie FREEWARE
An FTP and Archie client. Archie is a method of searching FTP sites for information.
ftp://ftp.csusm.edu/cwis/winworld/winsock/wsarchie.zip
159 KB

PING, *WINCHAT*, View, Winarch, Trumptel(Telnet) FREEWARE
A group of standard applications which allow you to retrieve IP and DNS information, conduct network tests, perform online "chat" sessions with other users, and enable virtual terminal access to remote hosts.
ftp://ftp.utas.edu.au/pc/trumpet/winsock/winapps2.zip
124 KB

WinGopher - *Macintosh* version available. FREEWARE
A Gopher client for *Windows*. Enables the download of files from Gopher servers.
bcinfo.bc.edu/pub/bcgopher/BCC08BA3.EXE
170469bytes

LView 31 FREEWARE
Graphic image viewer and processor.
file://gatekeeper.dec.com/.f/micro/msdos/win3/desktop/lview31.zip
234 KB

Wham - Version 1.31 $20-$30 DONATION ENCOURAGED - SHAREWARE
Audio file viewer and processor.
ftp://gatekeeper.dec.com/pub/micro/msdos/win3/sounds/wham131.zip
138 KB

Quicktime - Version 1.1 - *Macintosh* version available. SHAREWARE
A quicktime movie viewer.
bcinfo.bc.edu/pub/bcgopher/qtw11.exe
622 KB

MPEGXING FREEWARE
An MPEG movie viewer.
ftp://bcinfo.be.edu/pub/bcgopher/MPEGEXING.EXE
478 KB

WinZip 5.5a w/built-in ZIP+UNZIP; Drag & Drop SHAREWARE $29
Create compressed archives and decompress common *Windows* archived formats.
http://www.acs.oakland.edu/oak/SimTel/win3/winzip55.exe
284 KB

NCSA Collage for Winsock - *Macintosh* version available. FREEWARE
A shared whiteboard application.
ftp.cica.indiana.edu/pub/pc/win3/winsock/col_12b1.zip
204 KB

Hotmetal - HTML Editor FREE FOR EDUCATIONAL USE
A Hyper Text Markup Language (HTML) editor.
gatekeeper.dec.com/pub/net/infosys/NCSA/Web/html/hotmetal/hotmetal.exe
1361 KB

CU-SeeMe - *Macintosh* version available. FREEWARE
Point-to-point videoconferencing.
ftp://CU-SeeMe.cornell.edu/pub/video/PC.CU-SeeMe
224 KB

F-Prot Anti-virus SHAREWARE $20
Virus detection and removal software.
http://ici.proper.com/pc/files/fprot.zip
514 KB

Adobe Acrobat Reader - *Macintosh* version available. SHAREWARE
A Portable Document Format (.pdf) file viewer.
ftp://ftp.adobe.com/pub/adobe/Applications/Acrobat/Windows
1438 KB

GhostScript for *Windows* - *Macintosh* version available. FREEWARE
A *PostScript* (.ps) file viewer.
http://www.cs.wisc.edu/~ghost/ghostscript/obtaina.html

504 KB	gs333ini.zip	- Configuration, initialization, and example files.
440 KB	gs333win.zip	- MS-Windows 16 bit version.
1344 KB	gs333fn1.zip	- *GhostScript* standard fonts.
576 KB	gsview13.zip	- *GSview* previewer.

APPENDIX C. EIA/TIA-568B WIRING SCHEME IN A 10BASE-T PLUG

This is a drawing of the 10BASE-T plug specified in the IEEE 802.3 standard [IEEE, 90b]. The connector is commonly (and improperly) called an RJ-45. The proper name is an eight position modular plug. It connects 4 pairs of wires as shown below. The wiring scheme is simple in concept, yet somewhat time consuming in practice. Be sure to verify all wiring with a 10BASE-T tester box immediately after connection. More information on the design of 10BASE-T local area networks can be found in Chapter V.

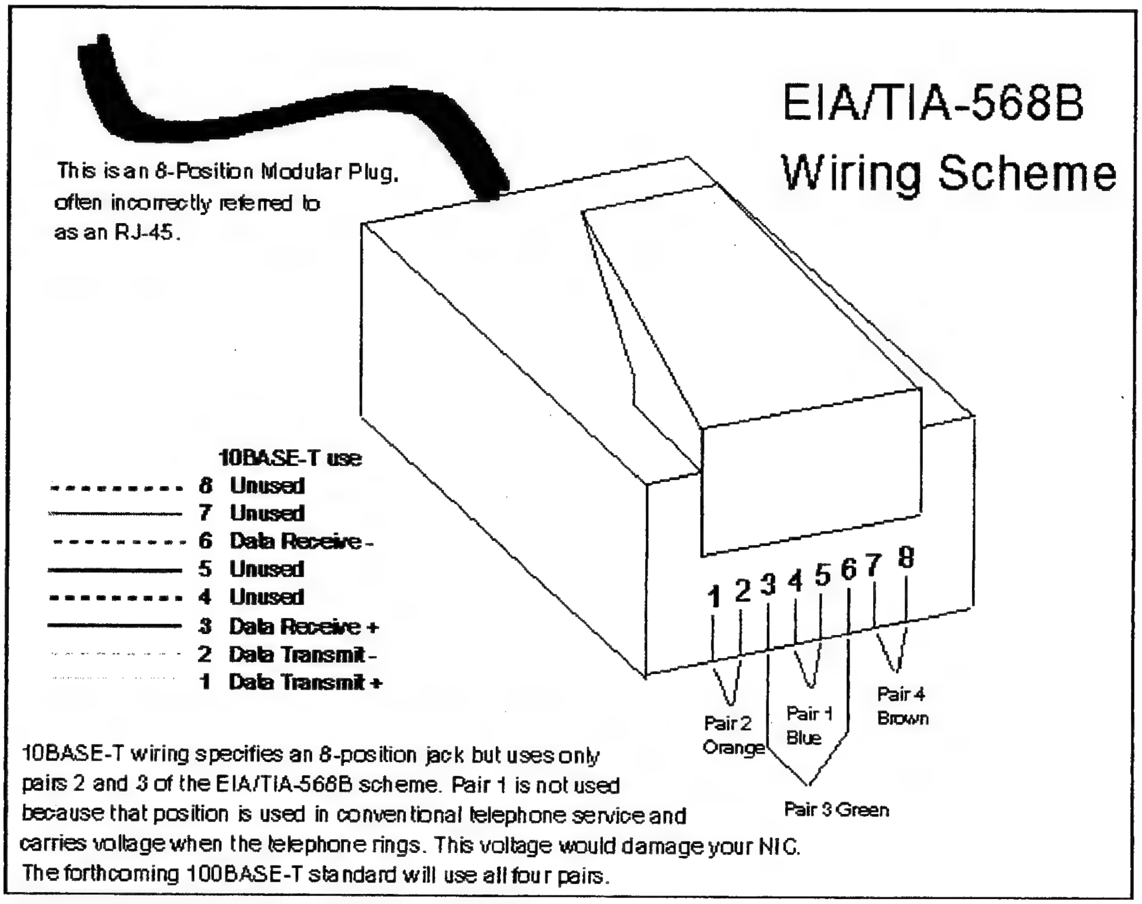


Figure C.1 EIA/TIA-568B wiring scheme.

APPENDIX D. EXAMPLE LAN DESIGNS

Local area network (LAN) design was discussed in detail in Chapter V. The following designs are typical of those that have been built within Monterey BayNet schools. The first design (Figure D.1) is from the Main Street School in Soledad California. Faculty members pulled new category 5 wire from a central 10BASE-T hub located at the MPOE to two computer labs located on the campus. The central hub has excess capacity (unused jacks), as do the hubs installed in the two classrooms. This will make future expansion to other areas on the campus easy and affordable. The LAN is connected to the WAN with a *Cisco* 2511 router and *Adtran* TSU. The 2511 will also act as a terminal server, allowing dial-in access to the WAN via a bank of 8 modems. Main Street School has a 128Kbps Frame Relay connection to Monterey BayNet. All LAN internal connections use Ethernet. This is the recommended model for school LAN design (i.e. A 10BASE-T LAN with a central hub at the MPOE servicing hubs in each building).

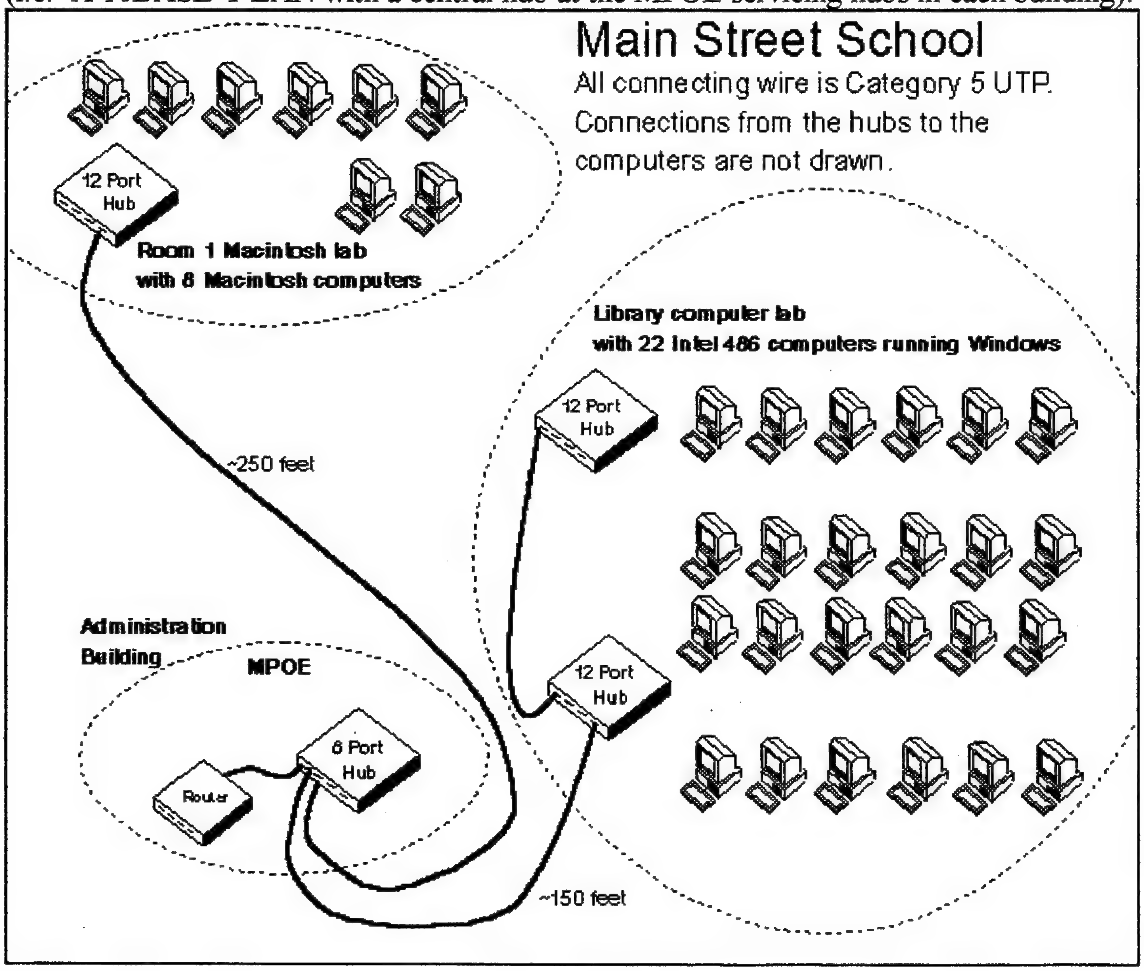


Figure D.1 Main Street School 10BASE-T LAN

Seaside High School (Figure D.2) has a 10BASE2 backbone serving 11 nodes. Two of the nodes are hubs which allow 10BASE-T connections to 12 Quadra 610s. Three other Quadras are attached directly to the backbone in the reading room. The circulation desk, office and file server are IBM clones with 486 processors. Novell Netware 4.1 is the network operating system. The LAN is connected to the WAN with a Cisco 2511 router and Adtran TSU. The 2511 will also act as a terminal server, allowing dial-in access to the LAN via a bank of 8 modems. Seaside High has a 128Kbps Frame Relay connection to Monterey BayNet.

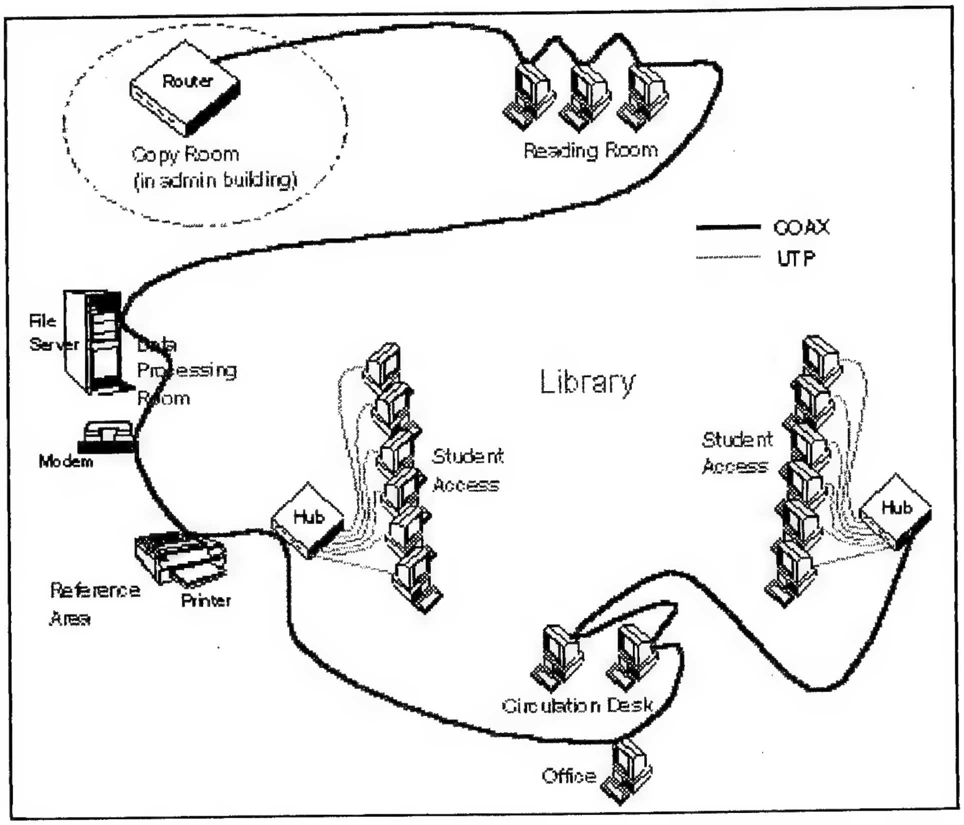


Figure D.2 Seaside High School Library 10BASE-2 LAN

The Monterey Bay Technology Education Center (MBTEC) and Fitch Middle School share a common campus. A single 384 Kbps Frame Relay line services both clients via a Cisco 2514 dual port router (Figure D.3). MBTEC has a 10BASE2 backbone serving a single node. The node is a 24 port hub which is directly connected to a second 24 port hub. The two hubs service a 10BASE-T raceway spanning all four rooms of the MBTEC facility. Novell Netware 4.1 is the network operating system. The file server is physically located in room A-4.

The Fitch Middle School LAN is a 10BASE-T network originating at the Cisco 2514 router and servicing a 12 port hub in the library. The circulation desk, reference

area and file server are IBM clones with 486 processors. Novell Netware 4.1 is the network operating system. The student access area is a cluster of Macintosh platforms. All library devices are connected to the hub with Category 5 UTP wire.

Note that a hub was not placed at the MPOE. When the administration building desires to connect to the LAN a hub will be required at the MPOE. The present design meets all current requirements and allows for easy expansion.

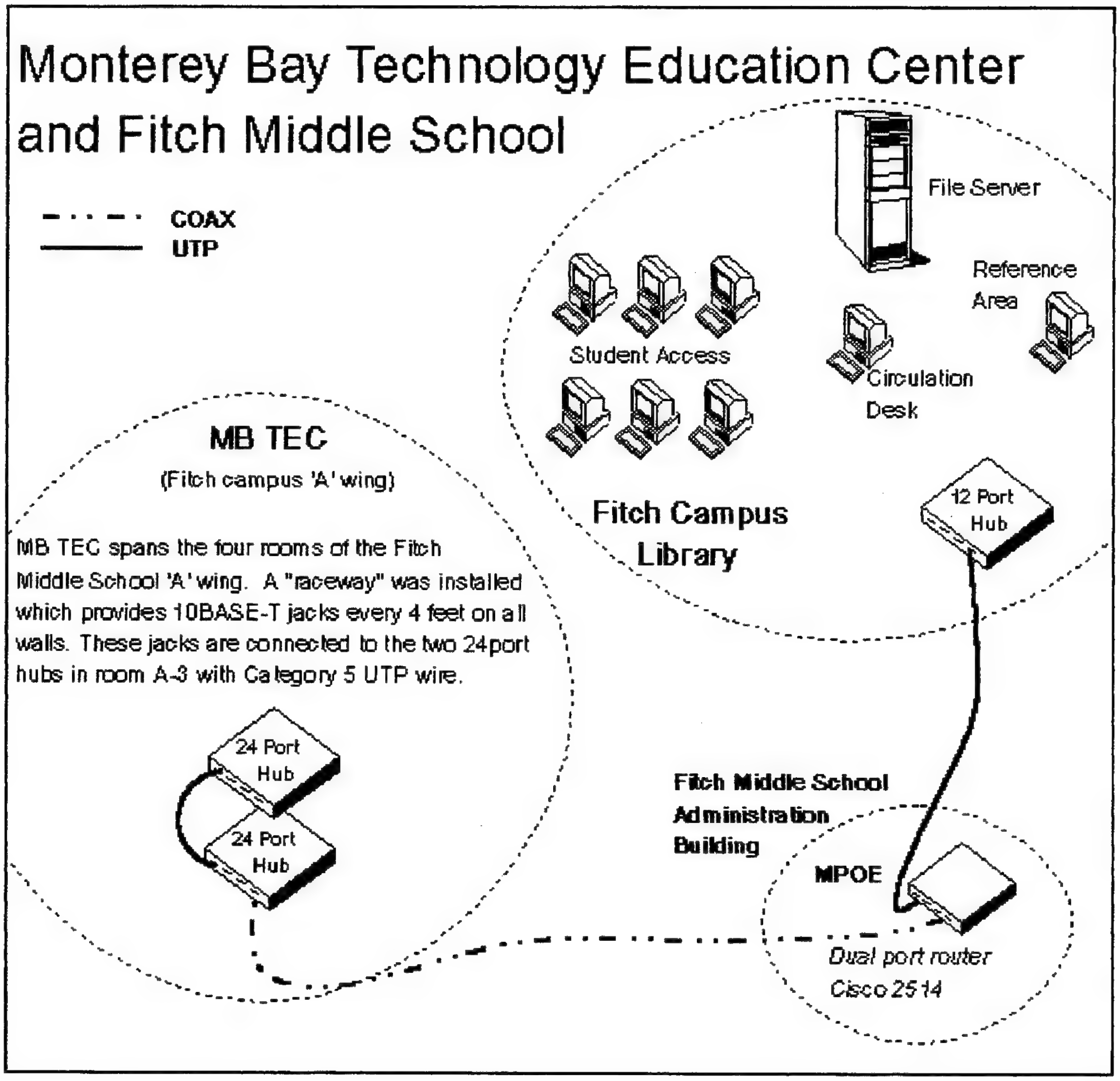


Figure D.3 Monterey Bay Technology Education Center (MBTEC) and Fitch Middle School LAN's connected by a *Cisco* 2514 dual port router.

APPENDIX E. MONTEREY BAYNET EQUIPMENT RECOMMENDATIONS

These are the original Monterey BayNet equipment recommendations. Chapters V, VI and VII have noted repeatedly the benefits of equipment standardization throughout LAN and WAN design. It is also be noted that technology evolves rapidly, delivering better and cheaper products to market. Always consult with the WAN system administrator and/or Internet provider prior to purchasing new equipment. The following recommendations were published in March 1995 [Herbst, 95a]. Prices, delivery terms, and warranty are subject to change, caveat emptor.

Router:

Cisco 2500 series:
Cisco 2514 Dual LAN router (recommended)
Cisco 2501 Single LAN router
Cisco 2511 Single LAN router with terminal service

CSU/DSU:

Adtran:
T1 CSU for 128Kbps thru 1.5Mbps Frame Relay service
Model *Adtran* TSU — $902.00
ADN CSU for 56Kbps Frame Relay service (not scalable)
Model *Adtran* 56/64 — $225.00

Ethernet Card:	*Eagle/Artisoft* EP2000+		$74.83
Smart Hubs (SNMP agent - recommended):			
Asante	AH1012-12 w/SNMP	99-00028-01	$750.00
Asante	*Netstacker* Base 24	99-00188-01	$1199.00
Cabletron	10 T 12 Port	SEHI-22	$1140.00
Cabletron	10 T 24 Port	SEHI-24	$1430.00
Allied Telesyn	10 T 24 port	AT-3624TRS-15	$673.00
Non-Intelligent Hubs (not recommended):			
Cabletron	10 T 12 Port	SEH-22	$575.00
Cabletron	10 T 24 Port	SEH-24	$812.00
Asante	10 T HUB 8 port	99-00299-01	$149.00
Asante	10 T HUB 12 port	99-00280-01	$299.00
Asante	10 T HUB 24 port	99-00281-01	$395.00

Allied Telesyn	10 T 12 port	AT-3612TR-15	$517.40
Allied Telesyn	10 T 12 port	AT-3612TR-18	$618.80
Allied Telesyn	10 T 14 port	AT-3624TR-15	$777.40
Allied Telesyn	10 T 14 port	AT-3624TR-18	$878.80

Network management program for *Windows* (Not available for Mac)

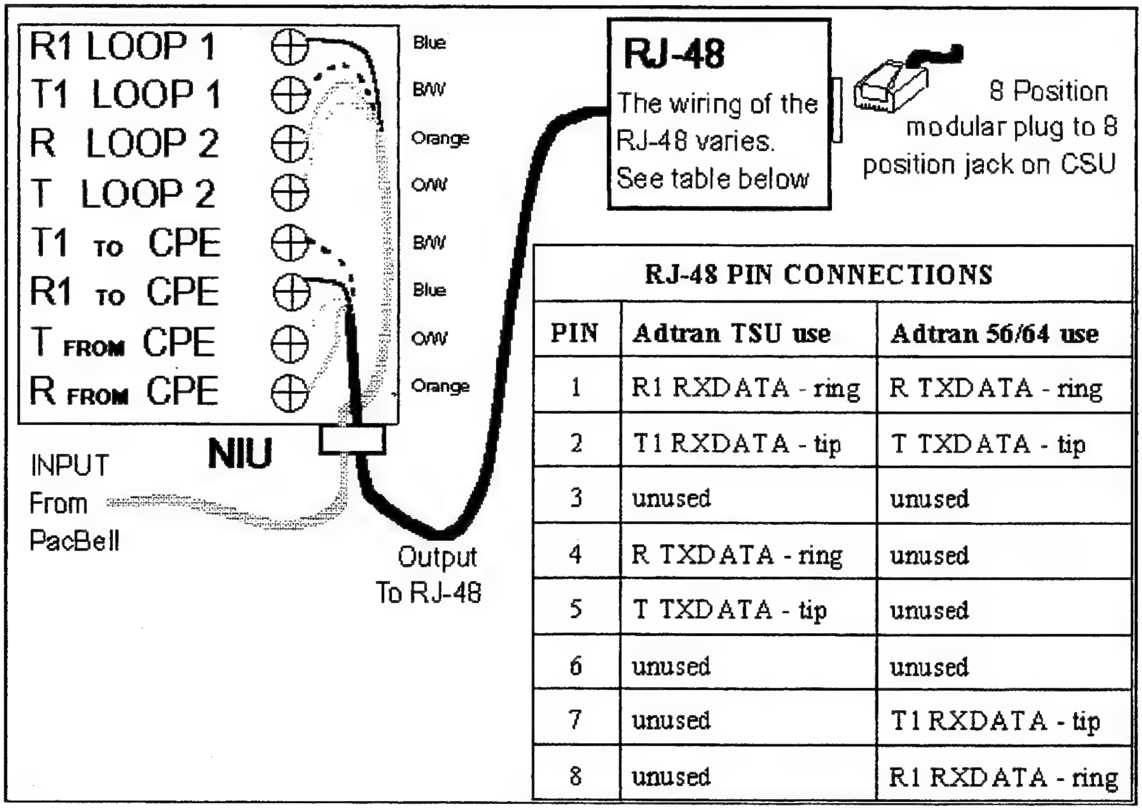
Castlerock SNMPc 3600 Release 3.3	AT-10070	$257.00

APPENDIX F. REGISTERED JACK NUMBER 48 (RJ-48) PINOUT AND WIRING BETWEEN NIU AND CSU

The Figure F.1 shows the physical wiring installed by PacBell at the minimum point of entry (MPOE) as described in Chapter VI. Recall that PacBell charges for the installation of the RJ-48. Monterey BayNet recommends that PacBell install the RJ-48 in those cases where the RJ-48 is not collocated with the PacBell Network Interface Unit (NIU).

Wiring from the NIU to the RJ-48 consists of 2 pairs of 24 gauge wire. The pairs are terminated on the punchdown block of the RJ-48 as described in the RJ-48 pin connections table below [Adtran, 94]. Note that the RJ-48 pinout varies depending upon the type of channel switching unit at the site.

The cable from the RJ-48 to the CSU is provided with the CSU. The cable is an 8 position modular plug to 8 position modular plug wired straight-thru using the EIA/TIA-568B wiring scheme discussed in Appendix C.



RJ-48 PIN CONNECTIONS

PIN	Adtran TSU use	Adtran 56/64 use
1	R1 RXDATA - ring	R TXDATA - ring
2	T1 RXDATA - tip	T TXDATA - tip
3	unused	unused
4	R TXDATA - ring	unused
5	T TXDATA - tip	unused
6	unused	unused
7	unused	T1 RXDATA - tip
8	unused	R1 RXDATA - ring

Figure F.1 RJ-48 pinout and wiring between NIU and CSU.

APPENDIX G. CHANNEL SERVICE UNIT/DIGITAL SERVICE UNIT (CSU/DSU) CONFIGURATION

Chapter VI described the role of the CSU/DSU in the WAN. Figure G.1 is the *Adtran* T-1 Service Unit (TSU) configuration menu tree with settings for a 128Kbps site. The *Adtran* TSU performs the role of both CSU and DSU [*Adtran*, 94]. The Channel Service Unit (CSU) function allows the TSU to be programmed to accept any number of channels up to a full T-1 service rate of 1.5 Mbps. Each channel is 64Kbps. 128 Kbps sites select two channels, sites with rates higher than 128Kbps adjust the number of channels accordingly. The Digital Service Unit (DSU) function programs the position of the data in the T-1 stream.

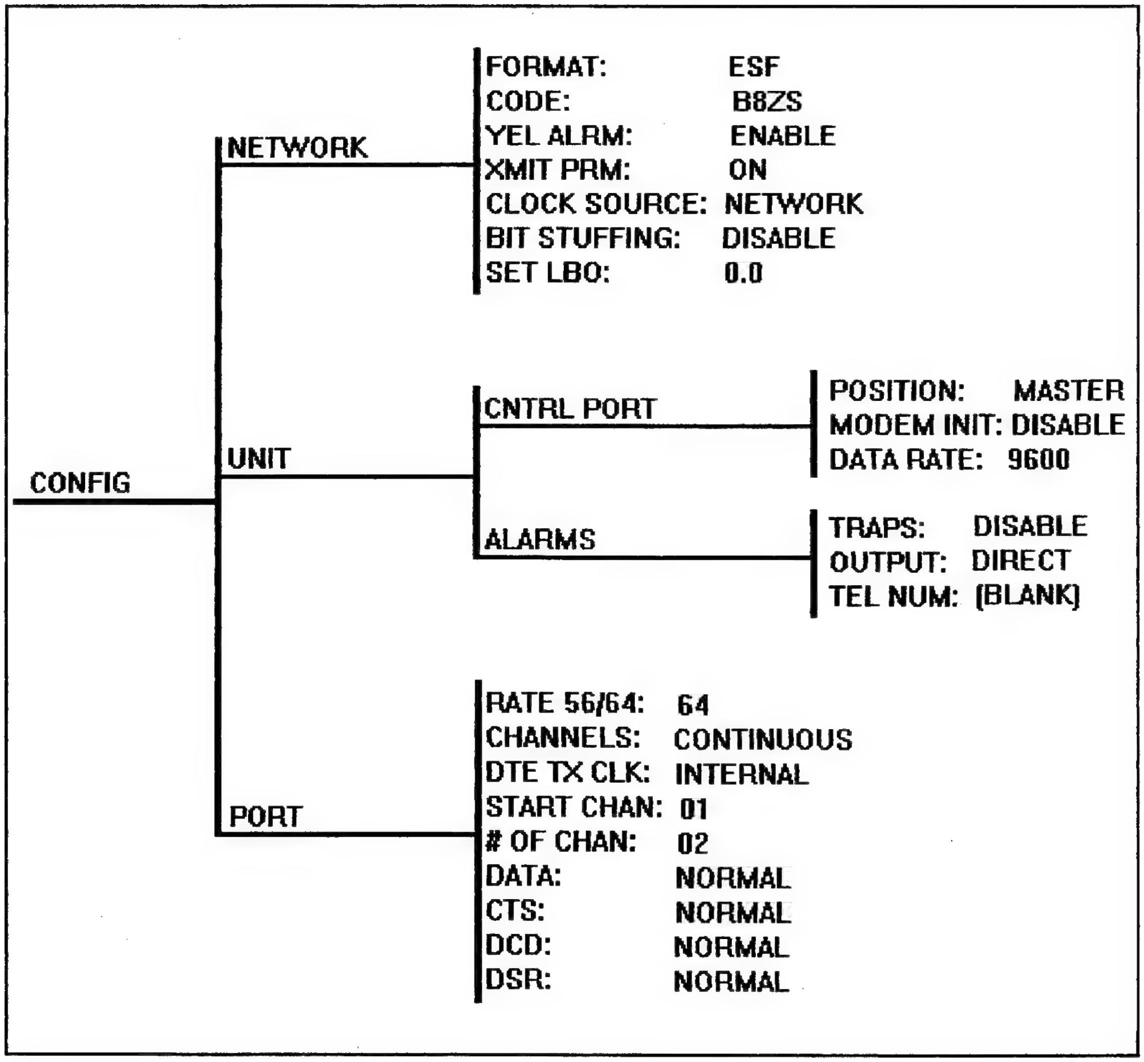


Figure G.1 *Adtran* TSU configuration menu tree with settings for a 128 Kbps site [*Adtran*, 94].

Figure G.2 is the dip-switch configuration of the *Adtran* 56/64 DSU. Note that the CSU function is not required since the site is not receiving the multiple channels associated with fractional T-1 lines.

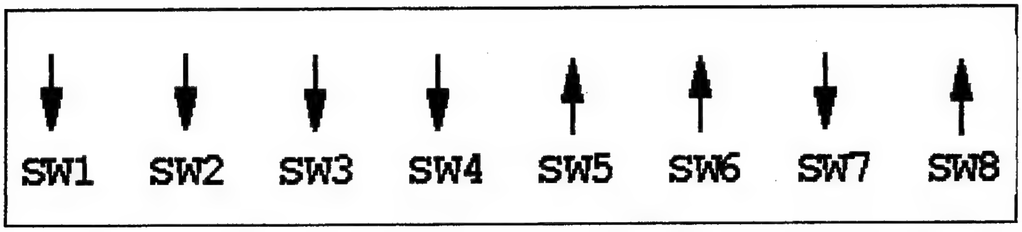


Figure G.2 *Adtran* 56/64 DSU dip-switch configuration (56 Kbps sites).

APPENDIX H. CISCO 2514 ROUTER CONFIGURATION

Chapter VI described the origin of the WAN and LAN configuration parameters used in the following configuration script. The script is included as an example of the router configuration process and to document a successful *Cisco* 2514 configuration script. The site being documented is the dual port LAN of Monterey High School and the Monterey Academy of Oceanographic Science (MAOS). In viewing the script note that a single physical WAN connection exists on serial port zero. Two PVC's are created linking the site to the Monterey County Office of Education (MCOE) and California State University Monterey Bay (CSUMB). The two links enable Internet access and Domain Name Service (DNS) respectively.

NOTE: If this is the first time you enter the *Cisco* router configuration program you will automatically get the global setup menu. If you need to change global parameters later, type "setup" while in the enable mode. This file is a copy of the initial setup script of a *Cisco* 2514 running version 10.2 software. Italic script indicates computer generated summary information. Capitalized and boldface information indicate user input. [] indicates *Cisco* default settings. No boldface answer indicates that the default settings enclosed in the [] brackets were used.

```
Would you like to enter the initial configuration dialog?
[yes]

First, would you like to see the current interface summary?
[yes]

Interface   IP-Address  OK?  Method   Status     Protocol
Ethernet0   unassigned  NO   not set   up         down
Serial0     unassigned  NO   not set   down       down
Serial1     unassigned  NO   not set   down       down

Configuring Global Parameters:

Enter host name [router]:    MHS
Enter enable password:     XXXXX
Enter virtual terminal password: CISCO
Configure SNMP Network Management? [yes]: NO
Configure DECnet? [no]:
Configure AppleTalk? [no]:
Configure IPX? [no]:
Configure Bridging? [no]:
Configure IP? [yes]:
Configure IGRP routing? [yes]:
Your IGRP autonomous System Number is [1]: 11
```

```
Configuring interface parameters:

Configuring interface Ethernet0:
Is this interface in use? [yes]:
Configure IP on this interface? [yes]:
IP address for this interface: 205.155.36.1
Number of bits in subnet field [0]:
Class C network is 205.155.36.0, 0 subnet bits; mask is
255.255.255.0

Configuring interface Ethernet1:
Is this interface in use? [yes]:
Configure IP on this interface? [yes]:
IP address for this interface: 205.155.54.1
Number of bits in subnet field [0]:
Class C network is 205.155.54.0, 0 subnet bits; mask is
255.255.255.0

Configuring interface Serial0:
Is this interface in use? [yes]:
Configure IP on this interface? [yes]: NO

Configuring interface Serial1:
Is this interface in use? [no]:

The following configuration command script was created:
hostname mhs
enable password XXXXX
line vty 0 4
password cisco
no snmp-server
!
no decnet routing
no appletalk routing
no  ipx routing
no bridge 1
ip routing
!
interface Ethernet0
ip address 205.155.36.1 255.255.255.0
no mop enabled
!
interface Ethernet1
```

```
ip address 205.155.54.1 255.255.255.0
no mop enabled
!
interface Serial0
no ip address
no mop enabled
!
interface Serial1
shutdown
no ip address
!
router igrp 11
network 205.155.36.0
network 205.155.54.0
!
end

Use this configuration? [yes/no]: YES
######[OK]
Use the enabled mode 'configure' command to modify this
configuration.
mmhs#CONFIG T

Enter configuration commands, one per line.  End with
CNTL/Z.
mhs(config)#IP NAME-SERVER 205.155.43.2
mhs(config)#INT S 0
mhs(config-if)#ENCAP FRAME-RELAY
mhs(config-if)#FRAME-RELAY LMI-TYPE ANSI
mhs(config-if)#INT S 0.1 POINT-TO-POINT
mhs(config-subif)#IP ADDR 198.189.239.22 255.255.255.252
mhs(config-subif)#FRAME-RELAY INTERFACE-DLCI 906 BROADCAST
mhs(config-subif)#ROUTER IRPG 11
mhs(config-router)#NETWORK 198.189.239.0
mhs(config-router)#INT S 0.1
mhs(config-subif)#DESCR ?  LINE  Up to 80 characters
describing this interface
mhs(config-subif)#descr MHS 2 MCOE CKT#50YBQQ275305-001,
DLCI 906
mhs(config-subif)#INT S 0.2 POINT-TO-POINT
mhs(config-subif)#IP ADDR 198.189.239.106 255.255.255.252
mhs(config-subif)#FRAME-RELAY INTERFACE-DLCI 806 BROADCAST
mhs(config-subif)#INT S 0.2
```

```
mhs(config-subif)#DESCR ?  LINE  Up to 80 characters
describing this interface
mhs(config-subif)#descr MHS 2 CSU CKT#50YBQQ275305-001, DLCI
806
mhs(config-subif)#^Z
mhs#%SYS-5-CONFIG_I: Configured from console by console
mhs#WR T
#####Current configuration:
!
version 10.2
!
hostname mhs
!
enable password XXXXX
!
interface Ethernet0
ip address 205.155.36.1 255.255.255.0
no mop enabled
!
Interface Ethernet1
ip address 205.155.54.1 255.255.255.0
no mop enabled
!
interface Serial0
no ip address
encapsulation frame-relay
frame-relay lmi-type ansi
!
interface Serial0.1 point-to-point
description MHS 2 MCOE CKT#50YBQQ275305-001, DLCI 906
ip address 198.189.239.22 255.255.255.252
frame-relay interface-dlci 906 broadcast
!
interface Serial0.2 point-to-point
description MHS 2 CSU CKT#50YBQQ275305-001, DLCI 806
ip address 198.189.239.106 255.255.255.252
frame-relay interface-dlci 806 broadcast
!
interface Serial1
no ip address
shutdown
!
router igrp 11
```

```
network 205.155.36.0
network 205.155.54.0
network 198.189.239.0
!
ip name-server 205.155.43.2
!
line con 0
line aux 0
line vty 0 4
password cisco
login
!
end
mhs#WR######[OK]
mhs#EXIT
```

APPENDIX I. MONTEREY BAYNET TOPOLOGY

The following Figures I.1 and I.2 are a graphical depiction of the Monterey BayNet topology as designed in Chapter VI. The images were created by Jim Warner of the University of California Santa Cruz using a Computer Aided Design (CAD) program. Updates to the images are presently available for anonymous file transfer from: *ftp.ucsc.edu/MBay-net/* or *monterey.k12.ca.us/pub/* the files are named *Mbaynet-Mont.ps* and *Mbaynet-SC.ps*. The '.ps' file extension indicates that the file is stored in PostScript format and requires a PostScript viewer or printer to display. Corresponding Universal Resource Locators (URLs) for these diagrams are:

- *ftp://ftp.ucsc.edu/MBay-net/Mbaynet-Mont.ps.*
- *ftp://ftp.ucsc.edu/MBay-net/Mbaynet-SC.ps.*
- *ftp://monterey.k12.ca.us/pub/Mbaynet-Mont.ps.*
- *ftp://monterey.k12.ca.us/pub/Mbaynet-SC.ps.*

The large circles in the diagram represent each of the sites. Each of them have a unique class C address from the 205.155.Y. block. The COEs are presented in the middle of the diagrams. At the top of each diagram is the Internet provider connection point, San Francisco State (SFSU) in Santa Cruz and CSU Monterey Bay (CSUMB) in Monterey. The heavy double line between SFSU and CSUMB represents the CSUnet backbone which connects each WAN (in addition to many other CSUnet sites) across the LATA boundary using Sprint as the primary long distance carrier.

Each line connecting two large circles is a PVC. The PVC is mapped to PacBell's assigned DLCI indicated by the smaller circle on the line. At each end of the PVC are the IP addresses which allow DLCI mapping. The Santa Cruz DLCI IP addresses are all from the 198.189.240.Z block; Monterey from 198.189.239.Z.

Note that the K-8 sites are forced to transit via the COEs in order to reach the Internet. High schools have direct access to the Internet provider without passing through the COE. See Chapter VI Section G for more details on this design decision.

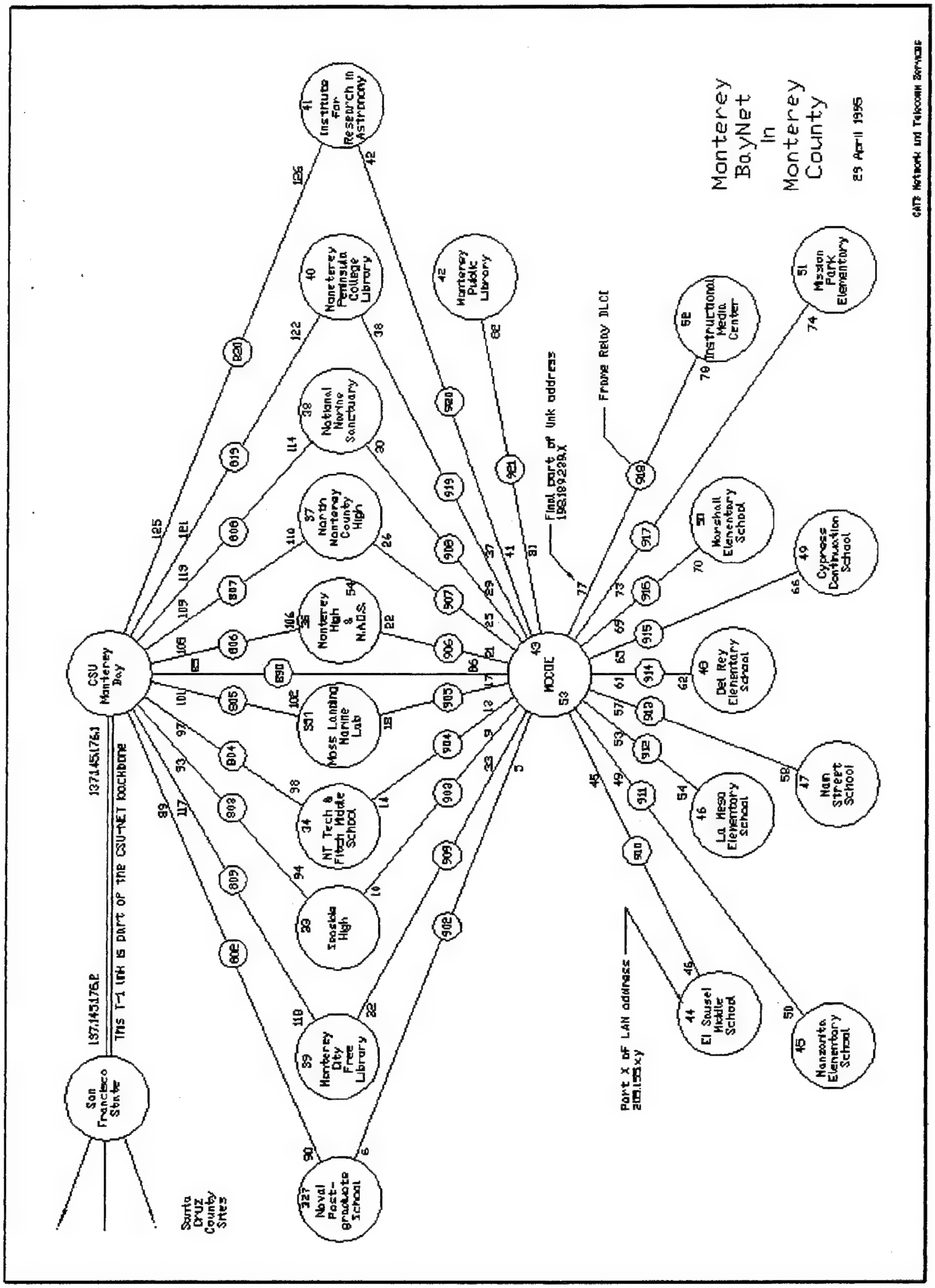


Figure I.1 Monterey BayNet in Monterey County
Available at *ftp://ucsc.edu/MBay-net/Mbaynet-Mont.ps.*

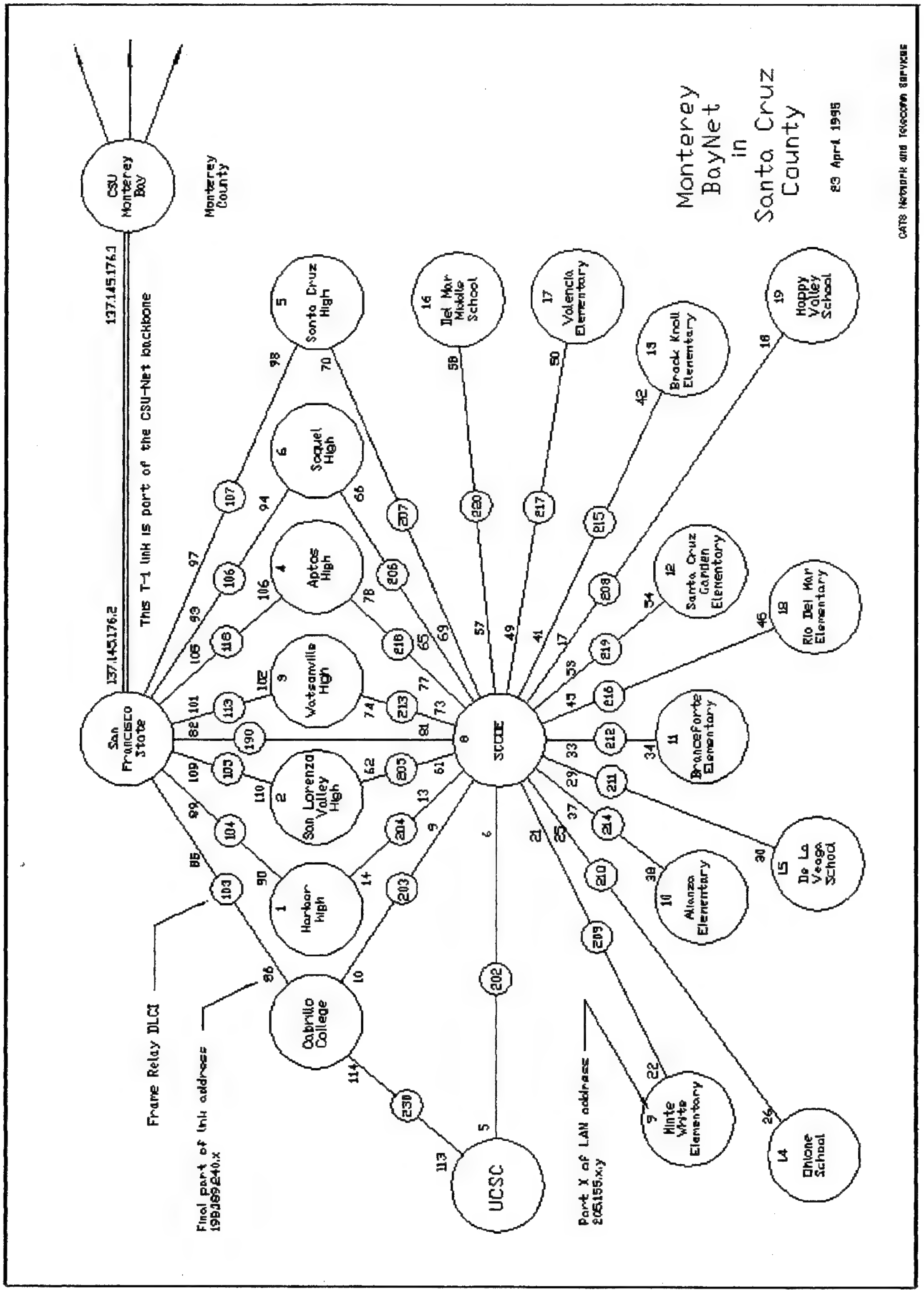


Figure I.2 Monterey BayNet in Santa Cruz County
Available at *ftp://ucsc.edu/MBay-net/Mbaynet-SC.ps*.

APPENDIX J. COMMITTED INFORMATION RATE (CIR) MATRIX

Chapter VI describes the WAN topology design process. Tables J.1 and J.2 are excerpted from PacBell's final work request inputs [Bellamy, 95]. PacBell stated that a approximately two hundred percent over-commitment of the Frame Relay lines would be allowed [Bellamy, 95]. The rate of over commitment is a negotiable value. Committed Information Rate (CIR) is PacBell's method of guaranteeing a worst case data exchange rate. This is of particular interest to customers who purchase full T-1 connectivity. On a full T-1 line Frame Relay the data is guaranteed to flow at the CIR and has the ability to "burst" to full T-1 speeds where the traffic permits. In the case of the Santa Cruz COE the CIR on DLCI 190 is 512 Kbps. At any given moment the actual data exchange rate between SFSU and SCCOE will be some rate between 512 Kbps and 1.5 Mbps depending upon traffic conditions at the switch. The CIR for each site is of less critical importance. The Frame Relay service can not "burst" to higher levels on a partial T-1 line because the unused channels are physically blanked out.

The total CIR in each LATA can be calculated by summing the CIR values and comparing the total with the physical line speed of the host. The sum of all Santa Cruz County Office of Education CIRs is 2.752 Mbps. Note that the CIR on DLCI 190 is only included once since this is physically the same PVC. Line speed at the Santa Cruz COE is 1.5 Mbps. Comparison shows that the SCCOE line is 179.2% overcommitted. If every SCCOE site tried to connect to the SCCOE at the same time some sites would experience delays. Fortunately many sites have an alternate route to the Internet which does not pass through the SCCOE and thus reduces the opportunity for congestion at the SCCOE.

Monterey County Office of Education has an even higher rate of over subscription. The total of all CIRs is 3.256. This yields a 220 percent oversubscription rate. Both counties are at the point where additional site connections will require the purchase of an additional T-1 line at the COE.

	Location	Line Speed	CIR Mbps	COE DLCI	SFSU DLCI	Addl DLCI	Install Date
1	Santa Cruz County Office of Education	1.536	.512		190		03/13/95
2	San Francisco State University	1.536	.512		190		03/14/95
3	University of California Santa Cruz	1.536	.384	202		230	03/15/95
4	Cabrillo College	0.384	.256	203	103	230	03/16/95
5	Harbor High School	0.128	.128	204	104		03/24/95
6	San Lorenzo Valley High	0.128	.128	205	105		03/24/95
7	Soquel High School	0.128	.128	206	106		03/30/95
8	Santa Cruz High School	0.128	.128	207	107		04/05/95
9	Happy Valley High School	0.128	.128	208			04/10/95
10	Minte White Elementry School	0.128	.128	209			04/14/95
11	Ohlone School/Pajaro Valley District	0.128	.128	210			04/20/95
12	De La Veaga School	0.056	.056	211			04/26/95
13	Branciforte Elementary School	0.056	.056	212			05/01/95
14	Watsonville High School	0.128	.128	213	113		05/05/95
15	Alianza School	0.056	.056	214			05/05/95
16	Brook Knoll Elementary School	0.056	.056	215			05/10/95
17	Rio Del Mar Elementary School	0.056	.056	216			05/16/95
18	Valencia Elementary School	0.056	.056	217			05/22/95
19	Aptos High School	0.128	.128	218	118		05/24/95
20	Santa Cruz Garden Elementary	0.056	.056	219			05/26/95
21	Del Mar Middle School	0.056	.056	223			12/95

Table J.1 Santa Cruz County Office of Education Committed Information Rate (CIR) matrix excerpted from PacBell's final work request inputs [Bellamy, 95].

	Location	Line Speed	CIR Mbps	COE DLCI	CSUMB DLCI	Install Date
1	Monterey County Office of Education	1.536	.512		890	03/07/95
2	California State University Monterey Bay	1.536	.512		890	03/14/95
3	United States Naval Postgraduate School	0.128	.128	902	802	03/09/95
4	Seaside High School Library	0.128	.128	903	803	03/10/95
5	Monterey Bay Technology Education Center	0.384	.384	904	804	03/22/95
6	Moss Landing Marine Laboratories	0.128	.128	905	805	04/04/95
7	Monterey High School	0.128	.128	906	806	04/03//95
8	North Monterey County High School	0.128	.128	907	807	04/07/95
9	Monterey Bay National Marine Sanctuary	0.128	.128	908	808	04/12/95
10	Monterey County Free Libraries	0.128	.128	909	809	04/18/95
11	El Sausel Middle School	0.128	.128	910		04/24/95
12	Manzanita Elementary School	0.128	.128	911		05/24/95
13	La Mesa Elementary School	0.128	.128	912		05/03/95
14	Main Street School	0.128	.128	913		03/23/95
15	Del Rey Elementary School	0.128	.128	914		05/12/95
16	Cypress Continuation School	0.128	.128	915		05/18/95
17	Marshall Elementary School	0.128	.128	916		04/28/95
18	Mission Park Elementary School	0.056	.056	917		05/30/95
19	Instructional Media Center (IMC)	0.128	.128	918		06/05/95
20	Monterey Peninsula College Library	0.128	.128	919	819	06/09/95
21	Monterey Institute for Research in Astronomy	0.128	.128	920	820	6/14/95
22	Monterey Public Library	0.128	.128	921		6/16/95

Table J.2 Monterey County Office of Education Committed Information Rate (CIR) matrix excerpted from PacBell's final work request inputs [Bellamy, 95].

APPENDIX K. OBTAINING AN IP NETWORK NUMBER

Chapter VI discussed the requirement for Internet Protocol (IP) network number registration with the InterNIC. The registration template is presented here for reference. The Monterey BayNet block of IP addresses were registered and issued by the Internet provider (CSUnet). The Universal Resource Locator (URL) for the latest copy of this registration template is *ftp://rs.internic.net/templates/internet-number-template.txt*

```
[ templates/internet-number-template.txt ]          [ 04/94 ]
This form must be completed as part of the application
process for obtaining an Internet Protocol (IP) Network
Number.  To obtain an Internet number, please provide the
following information on-line, via electronic mail, to
HOSTMASTER@INTERNIC.NET.  If electronic mail is not
available to you, please mail hardcopy to:

     Network Solutions
     InterNIC Registration Services
     505 Huntmar Park Drive
     Herndon, VA 22070
     -- OR --
     FAX to (703) 742-4811

Once Registration Services receives your completed
application we will send you an acknowledgement, via
electronic or postal mail.

NOTE: This application is solely for obtaining a legitimate
IP network number assignment.  If you're interested in
officially registering a domain please complete the domain
application found in templates/domain-template.txt.  If FTP
is not available to you, please contact
HOSTMASTER@INTERNIC.NET or phone the NIC at (800) 444-4345
(703) 742-4777 for further assistance.

YOUR APPLICATION MUST BE TYPED.

1) If the network will be connected to the Internet, you
must provide the name of the governmental sponsoring
organization or commercial service provider, and the name,
title, mailing address, phone number, net mailbox, and NIC
Handle (if any) of the contact person (POC) at that
```

organization who has authorized the network connection. This person will serve as the POC for administrative and policy questions about authorization to be a part of the Internet. Examples of such sponsoring organizations are: DISA DNS, The National Science Foundation (NSF), or similar government, educational or commercial network service providers.

NOTE: IF THE NETWORK WILL NEVER BE CONNECTED TO THE INTERNET, PLEASE UTILIZE THE ADDRESS SPACE RESERVED FOR NON-CONNECTED NETWORKS THAT IS SPECIFIED IN RFC 1597. IF YOU INTEND TO CONNECT THIS NETWORK TO THE INTERNET BUT HAVE NOT YET CHOSEN A SERVICE PROVIDER, LEAVE THIS SECTION BLANK, BUT INDICATE THE APPROXIMATE DATE OF YOUR INTERNET CONNECTION IN SECTION 9 OF THIS TEMPLATE. IF YOU INTEND TO CONNECT TO THE INTERNET AND HAVE ALREADY CHOSEN A PROVIDER, YOU ARE REQUIRED TO SUBMIT THIS REQUEST TO YOUR SERVICE PROVIDER FOR PROCESSING. SERVICE PROVIDERS ARE ALLOCATED BLOCKS OF ADDRESSES TO SUPPORT THE NETWORKING NEEDS OF THEIR CUSTOMERS. THIS PROCEDURE WILL ENSURE THAT THE NUMBER OF ENTRIES ADDED TO THE INTERNET ROUTING TABLES IS KEPT TO A MINIMUM, AND CIDR IS USED AS EFFICIENTLY AS POSSIBLE. THE ABOVE PROCEDURES PERTAIN EXCLUSIVELY TO REQUESTS FOR CLASS C ADDRESS(ES).

1a. Sponsoring Organization:
1b. Contact name (Lastname, Firstname):
1c. Contact title:
1d. Mail Address :
1e. Phone :
1f. Net mailbox :
1g. NIC handle (if known):

2) Provide the name, title, mailing address, phone number, and organization of the technical Point-of-Contact (POC). The on-line mailbox and NIC Handle (if any) of the technical POC should also be included. This is the POC for resolving technical problems associated with the network and for updating information about the network. The technical POC may also be responsible for hosts attached to this network.

2a. NIC handle (if known):
2b. Technical POC name (Lastname, Firstname):

2c. Technical POC title:
2d. Mail address :
2e. Phone :
2f. Net Mailbox :

3) Supply the SHORT mnemonic name for the network (up to 12 characters). This is the name that will be used as an identifier in internet name and address tables. The only special character that may be used in a network name is a dash (-). PLEASE DO NOT USE PERIODS OR UNDERSCORES. The syntax XXXX.com and XXXX.net are not valid network naming conventions and should only be used when applying for a domain.

3. Network name:

4) Identify the geographic location of the network and the organization responsible for establishing the network.

4a. Postal address for main/headquarters network site:
4b. Name of Organization:

5) Question #5 is for MILITARY or DOD requests, ONLY.

If you require that this connected network be announced to the NSFNET please answer questions 5a, 5b, and 5c. IF THIS NETWORK WILL BE CONNECTED TO THE INTERNET VIA MILNET, THIS APPLICATION MUST BE SUBMITTED TO HOSTMASTER@NIC.DDN.MIL FOR REVIEW/PROCESSING.

5a. Do you want MILNET to announce your network to the NSFNET? (Y/N):

5b. Do you have an alternate connection, other than MILNET, to the NSFNET? (please state alternate connection if answer is yes):

5c. If you've answered yes to 5b, please state if you would like the MILNET connection to act as a backup path to the NSFNET? (Y/N):

6) Estimate the size of the network to include the number of hosts and subnets/segments that will be supported by the network. A "host" is defined as any device (PC, printer etc.) that will be assigned an address from the host portion of the network number. A host may also be characterized as a node or device.

Host Information

6a. Initially:
6b. Within one year:
6c. Within two years:
6d. Within five years:

Subnet/Segment Information

6e. Initially:
6f. Within one year:
6g. Within two years:
6h. Within five years:

7) Unless a strong and convincing reason is presented, the network (if it qualifies at all) will be assigned a single class C network number. If a class C network number is not acceptable for your purposes, you are required to submit substantial, detailed justification in support of your requirements.

7. Reason:

8) Networks are characterized as being either Research, Educational, Government - Non Defense, or Commercial. Which type is this network?

8. Type of network:

9) What is the purpose of the network?

9. Purpose:

RECOMMENDED READING (available via anonymous FTP from DS.INTERNIC.NET (198.49.45.10), or call 1-800-444-4345 option #1)

Gerich, E. Guidelines for Management of IP Address Space, Ann Arbor, MI: Merit Network, Inc.; May 1993; RFC 1466. 10 p. (DS.INTERNIC.NET RFC1466.TXT).

Rekhter, Y., Moskowitz. B., Karrenberg, D., de Groot, G. Address Allocation for Private Internets, IBM Corp., Chrysler Corp., RIPE NCC; March 1994; RFC 1597. 8 p. (DS.INTERNIC.NET RFC1597.TXT).

Braden, R.T.; Postel, J.B. Requirements for Internet Gateways. Marina del Rey, CA: University of Southern California, Information Sciences Inst.; 1987 June; RFC 1009. 55 p. (DS.INTERNET.NET POLICY RFC1009.TXT).

Internet Engineering Task Force, Braden, R.T. Requirements for Internet Hosts -- Communication Layers. Marina del Rey, CA: University of Southern California, Information Sciences Inst.; October 1989; RFC 1122. 116 p. (DS.INTERNIC.NET RFC1122.TXT).

Internet Engineering Task Force, Braden, R.T. Requirements for Internet Hosts -- Application and Support. Marina del Rey, CA: University of Southern California, Information Sciences Inst.; October 1989; RFC 1123. 98 p. (DS.INTERNIC.NET RFC1123.TXT).

Internet Activities Board. Internet Official Protocol Standards. 1994 March; RFC 1600. 34p. (DS.INTERNIC.NET POLICY RFC1600.TXT). [Note: the current version is always available as "STD 1".]

Mogul, J.; Postel, J.B. Internet Standard Subnetting Procedure. Stanford, CA: Stanford University; 1985 August; RFC 950. 18 p. (DS.INTERNIC.NET POLICY RFC950.TXT).

Postel, J.B. Internet Control Message Protocol. Marina del Rey, CA: University of Southern California, Information Sciences Inst.; 1981 September; RFC 792. 21 p. (DS.INTERNIC.NET POLICY RFC792.TXT).

Postel, J.B. Transmission Control Protocol. Marina del Rey, CA: University of Southern California, Information Sciences

Inst.; 1981 September; RFC 793. 85 p. (DS.INTERNIC.NET POLICY RFC793.TXT).

Postel, J.B. Address Mappings. Marina del Rey, CA: University of Southern California, Information Sciences Inst.; 1981 September; RFC 796. 7 p. (DS.INTERNIC.NET POLICY RFC796.TXT). Obsoletes: IEN 115 (NACC 0968-79)

Postel, J.B. User Datagram Protocol. Marina del Rey, CA: University of Southern California, Information Sciences Inst.; 1980 August 28; RFC 768. 3 p. (DS.INTERNIC.NET POLICY RFC768.TXT).

Postel, J.B. Internet Protocol. Marina del Rey, CA: University of Southern California, Information Sciences Inst.; 1981 September; RFC 791. 45 p. (DS.INTERNIC.NET POLICY RFC791.TXT).

Reynolds, J.K.; Postel, J.B. Assigned Numbers. Marina del Rey, CA: University of Southern California, Information Sciences Inst.; 1992 JUly; RFC 1340. 139p. (DS.INTERNIC.NET POLICY RFC1340.TXT). [Note: the current version is always available as "STD 2".]

APPENDIX L. MONTEREY BAYNET DOMAIN NAME SERVICE

The following Monterey BayNet sites have domain name service (DNS) entries as indicated below. Most individual school sites do not presently operate an Internet server. In the interim these DNS entries will be linked to their respective county office of education (205.155.8.2 and 205.155.43.2). When the site has established an Internet server the DNS will be corrected to reflect the IP address of that server. The registration process was performed as per Appendix M.

In designing the names balance needs to be found between clear descriptions and unclear acronyms. Note that DNS names are not case sensitive. Variations on a theme with upper and lower case letter will not work. Another consideration discovered in Monterey BayNet is that some seemingly appropriate acronyms have inappropriate connotations in a foreign language. In a largely bi-lingual population these considerations are vital. The final approval of DNS entries must reside with the site residents.

SANTA CRUZ COUNTY LANs & DNS

Ethernet	Site	DNS Name
205.155.1	Harbor High School	harborhs.santacruz.k12.ca.us
205.155.2	San Lorenzo Valley High	slvhs.santacruz.k12.ca.us
205.155.3	Watsonville High School	whs.santacruz.k12.ca.us
205.155.4	Aptos High School	aptoshs.santacruz.k12.ca.us
205.155.5	Santa Cruz High School	santacruzhs.santacruz.k12.ca.us
205.155.6	Soquel High School	soquelhs.santacruz.k12.ca.us
205.155.7	Cabrillo College	cabrillo.cc.ca.us
205.155.8	Santa Cruz County Office of Education	sccoe.santacruz.k12.ca.us
205.155.9	Mintie White Elementary	mw.santacruz.k12.ca.us
205.155.10	Alianza Elementary	alianza.santacruz.k12.ca.us
205.155.11	Branciforte Elementary	b40elem.santacruz.k12.ca.us
205.155.12	Santa Cruz Garden Elem	scg.santacruz.k12.ca.us
205.155.13	Brook Knoll Elementary	brknoll.santacruz.k12.ca.us
205.155.14	Ohlone School	ohlone.santacruz.k12.ca.us
205.155.15	De La Veaga School	delave.santacruz.k12.ca.us
205.155.16	Del Mar Middle School	delmar.santacruz.k12.ca.us
205.155.17	Valencia Elementary	valencia.santacruz.k12.ca.us
205.155.18	Rio Del Mar Elementary	riodelmar.santacruz.k12.ca.us
205.155.19	Happy Valley School	happyvalley.santacruz.k12.ca.us

MONTEREY COUNTY LANs & DNS

Ethernet	Site	DNS Name
205.155.32	Naval Postgraduate School Education Access Gateway	edac.nps.navy.mil
205.155.33	Seaside High School	shs.monterey.k12.ca.us
205.155.34	Monterey Bay Technology Education Center	mbtec.monterey.k12.ca.us
205.155.35	Moss Landing Marine Lab	mlml.calstate.edu
205.155.36	Monterey High School	mhs.monterey.k12.ca.us
205.155.37	North Monterey County High School	nmhs.monterey.k12.ca.us
205.155.38	Monterey Bay National Marine Sanctuary	mbnms.nos.noaa.gov
205.155.39	Monterey County Free Libraries	mcfl.monterey.lib.ca.us
205.155.40	Monterey Peninsula College Library	mpc.cc.ca.us
205.155.41	Monterey Institute for Research in Astronomy	mira.org
205.155.42	Monterey Public Library	monterey.lib.ca.us
205.155.43	Monterey County Office of Education	bill.monterey.k12.ca.us
205.155.44	El Sausel Middle School	elsaus.monterey.k12.ca.us
205.155.45	Manzanita Elementary	mz.monterey.k12.ca.us
205.155.46	La Mesa Elementary	lmesa.monterey.k12.ca.us
205.155.47	Main Street School	mainst.monterey.k12.ca.us
205.155.48	Del Rey Elementary	drey.monterey.k12.ca.us
205.155.49	Cypress Continuation	cyp.monterey.k12.ca.us
205.155.50	Marshall Elementary (lower campus)	marsh.monterey.k12.ca.us
205.155.51	Mission Park Elementary	mnpk.monterey.k12.ca.us
205.155.52	Monterey Peninsula Unified School District Instructional Media Center	imc.monterey.k12.ca.us
205.155.53	Monterey County Office of Education (secure)	mcoe.monterey.k12.ca.us
205.155.54	Monterey Academy of Oceanographic Science	maos.monterey.k12.ca.us
205.155.55	Fitch Middle School	fitch.monterey.k12.ca.us

APPENDIX M. INSTRUCTIONS FOR THE US DOMAIN TEMPLATE

A. SUMMARY

Chapter VI discussed the requirement for domain registration. Monterey BayNet registered with CSUnet, the Internet provider. Portions of the registration template are presented here for reference and to compare with the completed Monterey BayNet registration forms which follow. The Universal Resource Locator (URL) for the latest copy of the registration form is *ftp://rs.internic.net/templates/domain-template.txt*.

B. TEMPLATE

```
INSTRUCTIONS FOR THE US DOMAIN TEMPLATE                   [1/95]
(Do not use this template for: COM, EDU, NET, ORG, GOV)*
************************************************************
To register a host in the US domain, the US Domain Template
must be sent to the US Domain Registrar (US-Domain@ISI.EDU)
or contact of a delegated zone.

     Email:  US-Domain@ISI.EDU
     Fax:    310-823-6714
     Phone:  310-822-1511
     To:  US Domain Registrar
          USC/Information Sciences Institute
          4676 Admiralty Way, Marina del Rey, CA  90292

(1)  PLEASE SPECIFY WHETHER THIS IS A NEW APPLICATION,
MODIFICATION TO AN EXISTING REGISTRATION, OR DELETION.

(2)  THE NAME OF THE DOMAIN.  This is the name that will be
used in tables and lists associating the domain with the
domain server addresses.

============================================================
          TABLE:  US DOMAIN NAMING STRUCTURE
============================================================
```

<host>.<locality>.<state-code>.US = locality based names
<host>.CI.<locality>.<state-code>.US = locality; city gov. agency
<host>.CO.<locality>.<state-code>.US= locality; county gov. agency
<school>.<district>.K12.<state-code>.US = K thru 12th grade
<school>.PVT.K12.<state-code>.US = private K thru 12th grade
<school>.<locality>.<state-code>.US = locality opt:for PVT Sch
<school>.CC.<state-code>.US = community colleges

<school>.TEC.<state-code>.US = technical or vocational schools
<library-name>.LIB.<state-code>.US = libraries (CI, CO, State,PVT)
<State-agency>.STATE.<state-code>.US = state government agencies
<org-name>.GEN.<state-code>.US = statewide assoc,clubs,BBs's
<org-name>.MUS.<state-code>.US = museums
<org-name>.COG.<state-code>.US = councils of governments
<org-name>.DST.<state-code>.US = regional agencies or districts (not gov't & larger than city or county)
<federal-agency>.FED.US = federal government agencies
<org-name>.DNI.US = distributed national institutes (research, educational, cultural)
<org-name>.ISA.US = interstate authority (joint gov't authorities - multistate)
==

Domain Name Example: networthy.santa-clara.ca.us

(3) THE NAME OF THE ENTITY REPRESENTED, THAT IS, ORGANIZATION BEING NAMED. For example: The Networthy Corporation, not the name of the Network Service Provider or organization submitting the request.

(4) PLEASE DESCRIBE THE DOMAIN BRIEFLY.
For example: The Networthy Corporation is a consulting organization of people working with UNIX and the C language in an electronic networking environment. It sponsors two technical conferences annually and distributes a bimonthly newsletter.

(5) THE DATE YOU EXPECT THE DOMAIN TO BE FULLY OPERATIONAL.
For every registration, we need both the administrative and the technical contacts of a domain (questions 6 & 7) and we MUST have a network mailbox for each. If you have a NIC handle (a unique NIC database identifier) please enter it. (If you don't know what a NIC handle is leave it blank). Also the title, mailing address, phone number, organization, and network mailbox.

(6) THE NAME OF THE ADMINISTRATIVE HEAD OF THE "ORGANIZATION". The administrator is the contact point for administrative and policy questions about the domain. The Domain administrator should work closely with the personnel he has designated as the "technical contact" for his domain. In this example the Domain Administraror would be the Administrator of the Networty Corporation, not the Administrator of the organization running the nameserver

(unless it is the same person).

(7) THE NAME OF THE TECHNICAL AND ZONE CONTACT. The technical and zone contact handles the technical aspects of maintaining the domain's name server and resolver software, and database files. He keeps the name server running. More than likely, this person would be the technical contact running the primary nameserver.

****

PLEASE READ: There are several types of registrations:

(a) Delegation (i.e., a portion of the US Domain name space is given to an organization running nameservers to support that branch; For example, K12.TX.US, for all K12 schools in Texas). For (a) answer questions 8 and 9.

(b) Direct Registration of an IP Host. For (b) answer question 10.

(c) Direct Registration of a non-IP Host. For (c) answer question 11 and 12.

****

QUESTIONS FOR DELEGATIONS

(8) PRIMARY SERVER Information. It is required to supply both the Contact information as well as hardware/software information of the primary nameserver.

(9)* SECONDARY SERVER Information. It is required to supply the hardware and software information of all secondary nameservers. Domains must provide at least two independent servers that provide the domain service for translating names to addresses for hosts in this domain. If you are applying for a domain and a network number assignment simultaneously and a host on your proposed network will be used as a server for the domain, you must wait until you receive your network number assigment and have given the server(s) a net-address before sending in the domain application. Establishing the servers in physically separate locations and on different PSNs and/or networks is strongly recommended.

NOTE: For those applicants not able to run nameservers, or for non-IP hosts the Name Server information is not applicable. (See #10 and #11).

==

QUESTION FOR DIRECT IP HOSTS (If you answered 8&9 do not answer 10,11,12).

==

(10) WHAT DOMAIN NAME SYSTEM (DNS) RESOURCE RECORDS (RR) AND VALUES ARE TO BE ENTERED FOR YOUR IP HOST (MUST HAVE AN A RECORD).

++

Example: RRs for an INTERNET hosts.

```
(a) DOMAIN NAME (required)...:  Networthy.Santa-Clara.CA.US.
(b) IP ADDRESS (required)....:  A  128.9.3.123
(c) HARDWARE (opt)...........:  SUN-3/110
(d) OPERATING SYS (opt)......:  UNIX
(e) WKS (opt)................:  128.9.3.123. UDP (tftp) TCP
(ftp)
(f) MX (opt).................:  10  RELAY.ISI.EDU.
```

It is your responsibility to see that an IN-ADDR pointer record is entered in the DNS database. (For internet hosts only). Contact the administrator of the IP network your host is on to have this done. The US Domain administration does not administer the network and cannot make these entries in the DNS database.

==

QUESTIONS FOR NON-IP HOSTS (such as UUCP).

==

Many applicants have hosts in the UUCP world. Some are one hop away, some two and three hops away from their "Internet Forwarder", this is acceptable. What is important is getting an Internet host to be your forwarder. If you do not already have an Internet forwarder, there are several businesses that provide this service for a fee, (see RFC 1359 - Connecting to the Internet What Connecting Institutions Should Anticipate, ACM SIGUCCS, August 1992).

Sometimes local colleges in your area are already on the Internet and may be willing to act as an Internet Forwarder. You would need to work this out with the systems administrator. We cannot make these arrangements for you.

(11) INTERNET FORWARDING HOST INFORMATION

(11a) What is the name of your Internet forwarding host? For example: The host Yacht-Club.MDR.CA.US uses UUCP to connect to RELAY.ISI.EDU which is an Internet host. (i.e., RELAY.ISI.EDU is the forwarding host).

(11b) What is the name of your contact person at fowarding host? The Administrator of RELAY.ISI.EDU must agree to be the forwarding host for Yacht-Club.MDR.CA.US, and the forwarding host must know a delivery method and route to Networthy. No double MXing.

(11c) What is the mailbox of your contact? What is the mailbox of the administrator of the forwarding host.

```
Example:  Contact Name......:  John Smith
          Contact Email.....:  js@RELAY.ISI.EDU
```

(12) WHAT DOMAIN NAME SYSTEM (DNS) RESOURCE RECORDS (RR) AND VALUES ARE TO BE ENTERED FOR YOUR NON-IP HOST.

```
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
     Example: RRs for a NON-IP host (uucp).

     (a)  DOMAIN NAME (required).....: Yacht-Club.MDR.CA.US.
     (b)  HARDWARE (opt).............: SUN-3/110
     (c)  OPERATING SYS (opt)........: UNIX
     (d)  MX (required)..............: 10  RELAY.ISI.EDU.
```

* NOTE: All K12 schools, community colleges/technical schools, state and local governmentt agencies are required to register under the US domain. Only four year universities are allowed to register under EDU and only federal agencies are allowed under GOV. (See RFC 1480, "The US Domain" and RFC 1591, "The Domain Name System Structure and Delegation" for details.

C. COMPLETED DNS REGISTRATION FORM FROM THE SANTA CRUZ COUNTY OFFICE OF EDUCATION

```
1.   REGISTRATION TYPE
(N)ew (M)odify (D)elete..:  N

2.*  FULLY-QUALIFIED DOMAIN NAME:  santacruz.k12.ca.us.

3.   ORGANIZATION INFORMATION
3a.  Organization Name.....:  Santa Cruz County Office of
                              Education
3b.  Address Line 1........:  809 H Bay Avenue
3b.  Address Line 2........:
3c.  City..................:  Capitola
3d.  State.................:  Ca
3e.  Zip/Code..............:  95010

4.   DESCRIPTION OF ORG/DOMAIN:    The public schools in
                                   Santa Cruz County

5.   Date Operational......:  April 15, 1995

6.   ADMINISTRATIVE CONTACT OF ORG/DOMAIN
6a.  NIChandle (if known)..:
6b.  Whole Name............:  Rowland Baker
6c.  Organization Name.....:  Santa Cruz County Office of
                              Education
6d.  Address Line 1........:  809 H Bay Avenue
6d.  Address Line 2........:
6e.  City..................:  Capitola
6f.  State.................:  Ca
6g.  Zip/Code..............:  95010
6h.* Voice Phone...........:  408-476-5346
6i.* Electronic Mailbox....:  rowbake@telis.org

7.   TECHNICAL AND ZONE CONTACT
7a.  NIChandle (if known)..:
7b.  Whole Name............:  Lucas Fletcher
7c.  Organization Name.....:  Santa Cruz County Office of
                              Education
7d.  Address Line 1........:  809 H Bay Avenue
7d.  Address Line 2........:
7e.  City..................:  Capitola
7f.  State.................:  Ca
7g.  Zip/Code..............:  95010
7h.* Voice Phone...........:  408-476-7140
7i.* Electronic Mailbox....:dnsmgr@sccoe.santacruz.k12.ca.us
```

FILL OUT QUESTION 8 AND 9 FOR DELEGATIONS ONLY (i.e those organizations running nameservers for a branch of the US Domain namespace, for example: k12.<state>.us).

```
8.    PRIMARY SERVER: HOSTNAME, NETADDRESS
8a.   NIChandle (if known)..:
8b.   Whole Name............:   Lucas Fletcher
8c.   Organization Name.....:   Santa Cruz County Office of
                                Education
8d.   Address Line 1........:   809 H Bay Avenue
8d.   Address Line 2........:
8e.   City..................:   Capitola
8f.   State.................:   Ca
8g.   Zip/Code..............:   95010
8h.* Voice Phone...........:   408-476-7140
8i.* Electronic Mailbox....:dnsmgr@sccoe.santacruz.k12.ca.us
8j.   Hostname..............:   ns.santacruz.k12.ca.us
8k.* IP Address ...........:   205.155.8.2
8l.* HARDWARE..............:   Sun
8m.* OPERATING SYS.........:   Solaris 2.4

9. * SECONDARY SERVER: HOSTNAME, NETADDRESS
9a.* Hostname..............:   morris.ucsc.edu
9b.* IP Address............:   128.114.1.6
9c.* HARDWARE..............:   Sun
9d.* OPERATING SYS.........:   SunOS 4.1.3u
```

D. COMPLETED DNS REGISTRATION FORM FROM THE MONTEREY COUNTY OFFICE OF EDUCATION

```
1.    REGISTRATION TYPE
(N)ew (M)odify (D)elete..:  N

2.*   FULLY-QUALIFIED DOMAIN NAME:  monterey.k12.ca.us.

3.    ORGANIZATION INFORMATION
3a.   Organization Name.....:   Monterey County Office of
                                Education
3b.   Address Line 1........:   901 Blanco Circle
3b.   Address Line 2........:
3c.   City..................:   Salinas
3d.   State.................:   Ca
3e.   Zip/Code..............:   93912

4.    DESCRIPTION OF ORG/DOMAIN:    The Monterey County
                                    Office of Education is a
                                    non-profit California
                                    County government agency
```

5. Date Operational......: April 5, 1995

6. ADMINISTRATIVE CONTACT OF ORG/DOMAIN
6a. NIChandle (if known)..:
6b. Whole Name............: Michael Ottmar
6c. Organization Name.....: Monterey County Office of Education
6d. Address Line 1........: 901 Blanco Circle
6d. Address Line 2........:
6e. City..................: Salinas
6f. State.................: Ca
6g. Zip/Code..............: 93912
6h.* Voice Phone...........: 408-755-0308
6i.* Electronic Mailbox....: mottmar@mcoe.monterey.k12.ca.us

7. TECHNICAL AND ZONE CONTACT
7a. NIChandle (if known)..:
7b. Whole Name............: Michael Mellon
7c. Organization Name.....: Monterey County Office of Education
7d. Address Line 1........: 901 Blanco Circle
7d. Address Line 2........:
7e. City..................: Salinas
7f. State.................: Ca
7g. Zip/Code..............: 93912
7h.* Voice Phone...........: 408-755-0383
7i.* Electronic Mailbox....: mmellon@mcoe.monterey.k12.ca.us

FILL OUT QUESTION 8 AND 9 FOR DELEGATIONS ONLY (i.e those organizations running nameservers for a branch of the US Domain namespace, for example: k12.<state>.us).

8. PRIMARY SERVER: HOSTNAME, NETADDRESS
8a. NIChandle (if known)..:
8b. Whole Name............: Michael Mellon
8c. Organization Name.....: Monterey County Office of Education
8d. Address Line 1........: 901 Blanco Circle
8d. Address Line 2........:
8e. City..................: Salinas
8f. State.................: Ca
8g. Zip/Code..............: 93912
8h.* Voice Phone...........: 408-755-0383
8i.* Electronic Mailbox....: mmellon@mcoe.monterey.k12.ca.us
8j. Hostname..............: bill.monterey.k12.ca.us
8k.* IP Address ....: 205.155.43.2
8l.* HARDWARE..............: Sun
8m.* OPERATING SYS.........: Solaris 2.4

```
9. * SECONDARY SERVER: HOSTNAME, NETADDRESS
9a.* Hostname..............: morris.ucsc.edu
9b.* IP Address............: 128.114.1.6
9c.* HARDWARE..............: Sun
9d.* OPERATING SYS.........: SunOS 4.1.3u
```

APPENDIX N. REGISTERING FOR AN AUTONOMOUS SYSTEM NUMBER

Chapter VI discussed the requirement for Autonomous System (AS) registration with the InterNIC. Monterey BayNet is has not implemented any gateways and is not required to register as an AS at this time. Excerpts from the registration template are presented here for reference. The Universal Resource Locator (URL) for the latest copy of this registration template is *ftp://rs.internic.net/templates/asn-template.txt*

```
[ netinfo/asn-template.txt ]                          [ 09/94 ]
Registering for an Autonomous System Number implies that you
plan to implement one or more gateways and use them to
connect networks in the Internet.  Please provide us with
further details about your plans, and with information about
the administrative authority you have for participating in
the Internet.

It is strongly advised that you follow the development of
inter-autonomous systems protocols in the IAB task forces.

To obtain an Autonomous System Number the following
information must be provided:

1) The name, title, mailing address, phone number, and
organization of the administrative head of the organization.

2) The name, title, mailing address, phone number, and
organization of the technical contact.

3) The name of the autonomous system (up to 12 characters).
This is the name that will be used in tables and lists
associating autonomous systems and numbers.

4) A description of the gateway that implements the inter-
autonomous system protocol for interaction with other
autonomous systems. Currently the exterior gateway protocol
(EGP) is being used for this purpose (RFC 904).  This
gateway should comply with RFC 1009, Requirements for
Internet Gateways.

5) A description of the gateway hardware, including CPU and
interfaces.
```

6) A description of the gateway software, including operating system and languages.

7) The deployment schedule for the autonomous system.
   (a) initially,
   (b) within one year,
   (c) two years, and
   (d) five years.

8) What networks will be interconnected by these gateways? What are the internet addresses of each gateway?

RECOMMENDED READING (From Registration Services)

Mills, D.L. Exterior Gateway Protocol Formal Specification. 1984 April; RFC 904. 30 p. (RS.INTERNIC.NET POLICY RFC904.TXT).

Braden, R.T.; Postel, J.B. Requirements for Internet Gateways. 1987 June; RFC 1009. 55 p. (RS.INTERNIC.NET POLICY RFC1009.TXT).

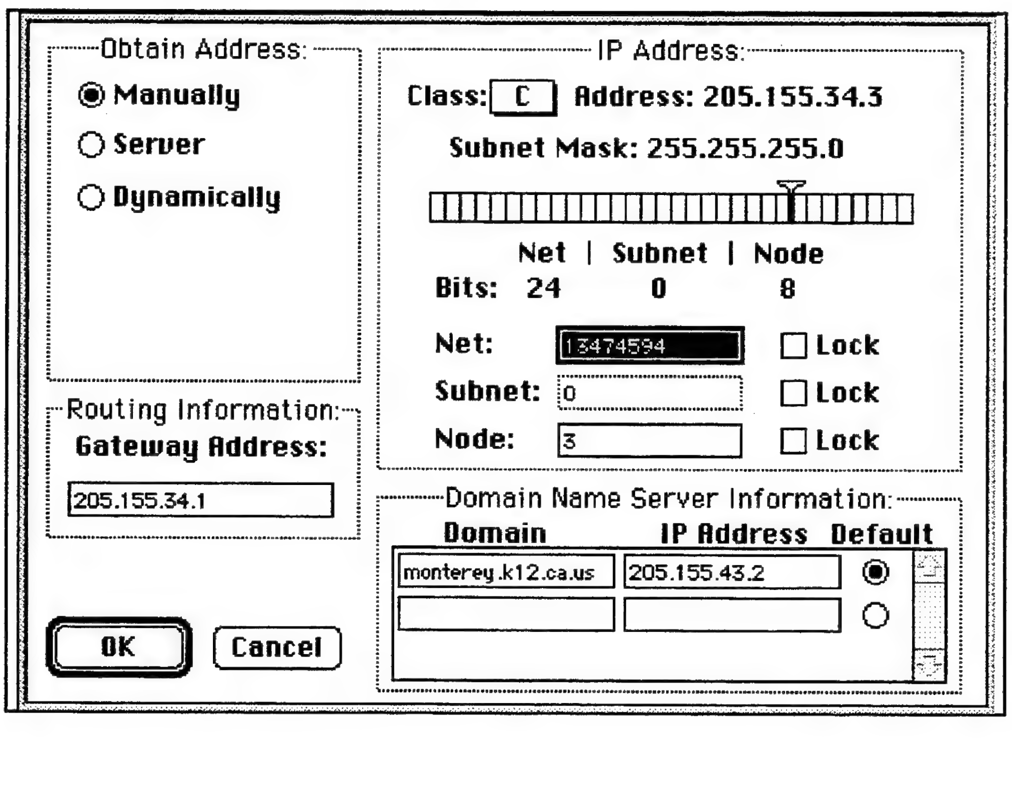
APPENDIX O. MACTCP CONFIGURATION

MacTCP is the proprietary software being used in Monterey BayNet to allow *Macintosh* products to "talk" Internet Protocol (IP). The easiest way to to obtain *MacTCP* is through the purchase of *The Internet Starter Kit for the Macintosh* (currently $29.95) at many bookstores [Engst, 94]. Version 2.0.6 comes bundled with operating system 7.5. A version 2.0.4 upgrade to 2.0.6 "patch" is available at *ftp://seeding.apple.com/mactcp/*. Monterey BayNet recommends using the MacTCP version that came bundled with system 7.5 or version 2.0.4. The "patched" version 2.0.6 is NOT recommended because it has been found to cause more errors than it fixes.

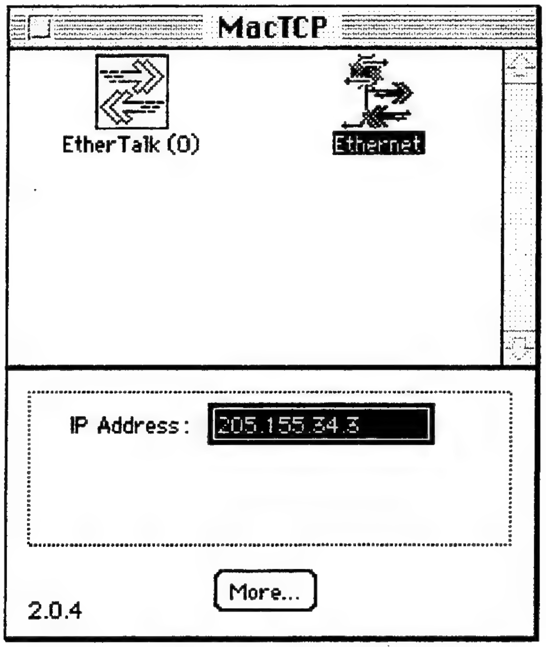
To Install MacTCP drag the MacTCP icon onto the system folder. Open MacTCP and immediately click on the "More..." button to expose the screen below.

Configure as below substituting appropriate IP addresses:
Monterey Domain Name/IP Address= **monterey.k12.ca.us 205.155.43.2**
Santa Cruz Domain Name/IP Address = **santacruz.k12.ca.us 205.155.8.2**
Gateway is the site router address = **205.155.y.1**

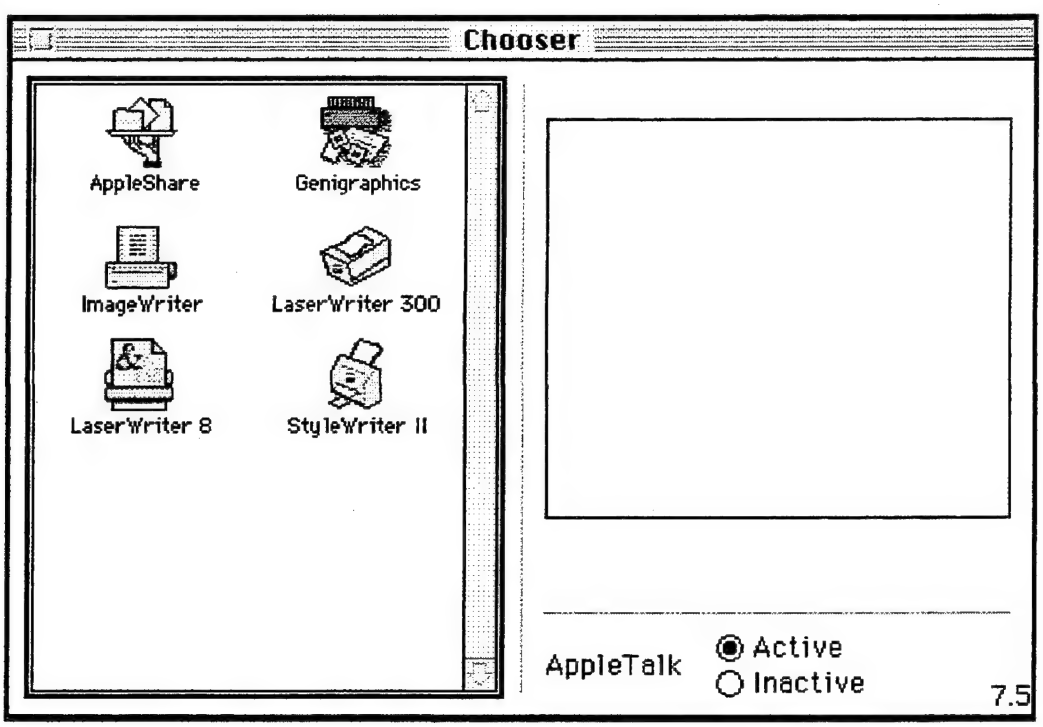
In the IP Address box change only the class do not attempt to modify the net, subnet or node. When complete click OK to bring back the opening screen.



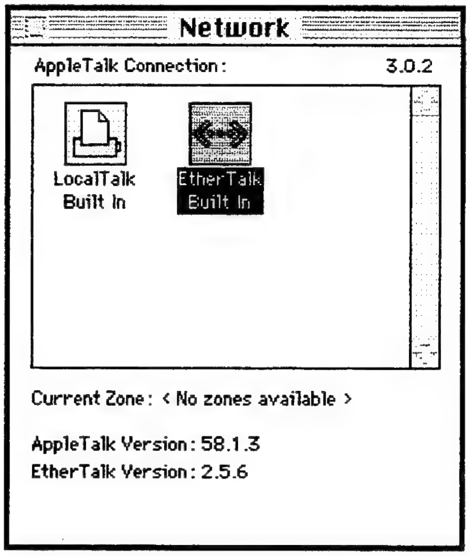
Input the IP address of the specific machine you are configuring. A good practice is to write the IP address and name of the terminal on the face of the terminal. This will avoid future confusion if the settings of MacTCP are lost. Select Ethernet by clicking on it.



Close MacTCP. You will be advised to restart the machine in order for the changes to take effect. Before restarting verify that AppleTalk is active in the Chooser by selecting "active" as shown below.



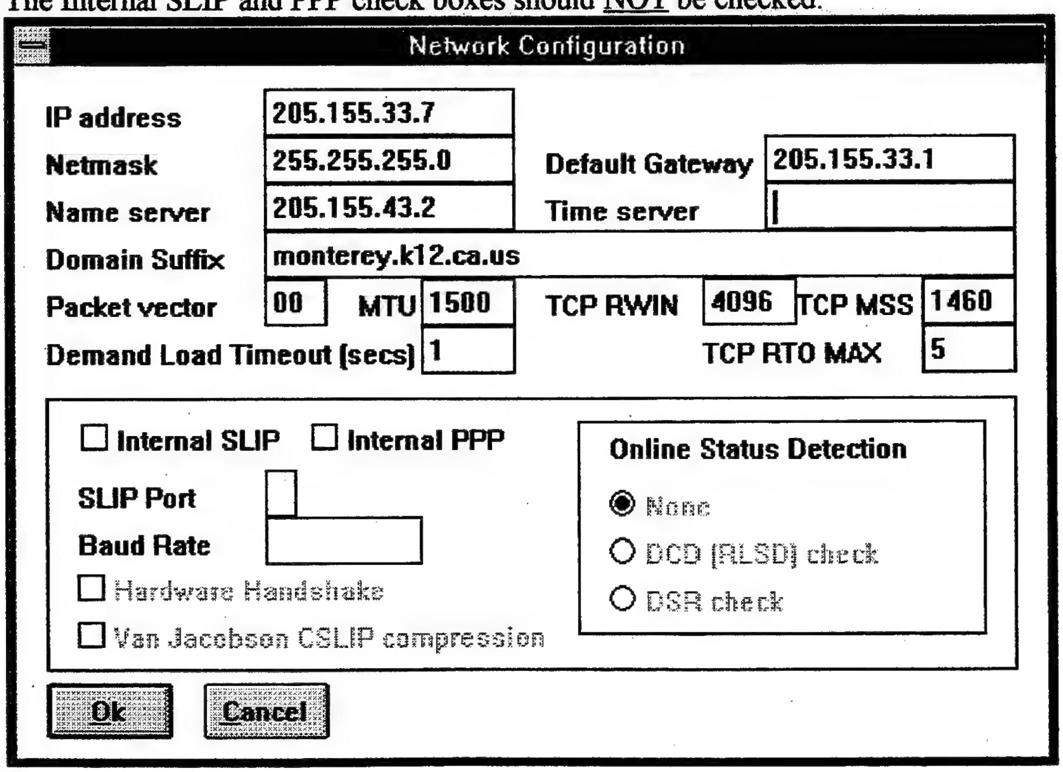
Verify that EtherTalk is selected in the Network control panel. The Macintosh is now configured for proper operation in future sessions. Restart your *Macintosh*, test and enjoy!



APPENDIX P. *WINDOWS* TRUMPET WINSOCK PACKET DRIVER CONFIGURATION

Install Trumpet Winsock as a packet driver in accordance with the install.txt file provided with the software. Trumpet Winsock can be obtained at the following URL: *ftp://ftp.cica.indiana.edu/ftp/pub/pc/win3/winsock/twsk20b.zip*.

The following configuration parameters have been tested in Monterey BayNet sites:
IP address: The IP address of the machine. (205.155.y.1 and 205.155.y.2 are the router and WWW server. 205.155.y.3 is the first terminal at the site, 205.155.y.254 the last). It is good practice to write the IP address on the face of the device.
Netmask: 255.255.255.0
Default Gateway: The site router IP address. 205.155.y.1
Name server: Monterey = 205.155.43.2
Santa Cruz = 205.155.8.2
Domain suffix: Monterey = monterey.k12.ca.us
Santa Cruz = scruz.k12.ca.us
Packet Vector: Default value of 00. The value must reflect the packet driver vector where the packet driver is installed. The number is expressed in hexadecimal without the leading "0x".
MTU: 1500 is maximum and recommended.
TCP RWIN: Defaults to 4096 but can be larger.
TCP MSS: Use the default of 1460.
The Internal SLIP and PPP check boxes should NOT be checked.



APPENDIX Q. ACRONYMS

ADN	Advanced Digital Network
AIF	Audio Interchange Format
ANSI	American National Standards Institute
ATM	Asynchronous Transfer Mode
.AU	Audio (file name extension)
AUI	Attachment Unit Interface
.BMP	Bitmap Picture (file name extension)
BRI	Basic Rate Interface
CalREN	California Research and Education Network
CIR	Committed Information Rate
CNE	Certified NetWare Engineer
COE	County Office of Education
CSMA/CD	Carrier Sense Multiple Access/with Collision Detection
CSU	Channel Service Unit
CTS	Clear To Send
DLCI	Data Link Control Identifier
DLL	Dynamic Link Library
DoD	Department of Defense
DoN	Department of the Navy
DS	Data Send
DSU	Digital Service Unit
EIA	Electronic Industries Association
.EXE	Executable (file name extension)
FDDI	Fiber Distributed Data Interface
FTP	File Transfer Protocol
Gb	Gigabit
GB	Gigabyte
.GIF	Graphics Interchange Format (file name extension)
GUI	Graphical User Interface
.gz	*Gzip* compressed file (file name extension)
HiCap	High Capacity Digital Service
.HQX	BinHexed (file name extension)
HTML	HyperText Markup Language
HTTP	HyperText Transport Protocol
I^3LA	Initiative for Information Infrastructure and Linkage Applications
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IGP	Interior Gateway Protocol
IGRP	Interior Gateway Routing Protocol
IMAP	Internet Message Access Protocol
IP	Internet Protocol

IPX	Internetwork Packet eXchange
ISDN	Integrated Services Digital Network
JFIF	JPEG File Interchange Format
JPEG	Joint Photographic Experts Group
K-12	Kindergarten through 12th Grade
KB	Kilobyte
KBPS	Kilobits Per Second
LAN	Local Area Network
LATA	Local Access Transport Area
LED	Light-Emitting Diode
LMI	Local Management Interface
LZW	Lempel-Ziv-Walsh
MAC	Medium Access Control
.MAC	MacPaint (file name extension)
MAOS	Monterey Academy of Oceanographic Science
MBARI	Monterey Bay Aquarium Research Institute
MBone	Multicast Backbone
Mbps	Megabits per second
MB ReEF	Monterey Bay Regional Education Futures
MB TEC	Monterey Bay Technology Education Center
MCOE	Monterey County Office of Education
MPEG	Moving Picture Experts Group
MPOE	Minimum Point of Entry
NCC	Network Control Center
NCSA	National Center for Supercomputing Applications
NESC	National Electrical Safety Code
NIC	Network Information Center / Network Interface Card
NII	National Information Infrastructure
NIU	Network Interface Unit
NNTP	Network News Transfer Protocol
NOAA	National Oceanic and Atmospheric Administration
NOC	Network Operations Center
NPS	Naval Postgraduate School
NRC	National Research Council
OSPF	Open Shortest Path First
.PDF	Printer Description File (file name extension)
PICT	Picture file
POP	Post Office Protocol
PPP	Point-to-Point Protocol
PRI	Primary Rate Interface
.PS	PostScript f(file name extension)
PVC	Permanent Virtual Circuit
REINAS	Real-Time Environmental Information Network and Analysis System

RFC	Request For Comments (See bibliography)
RIP	Routing Information Protocol
RJ	Registered Jack
RLE	Run Length Encoded
SCCOE	Santa Cruz County Office of Education
SFSU	San Francisco State University
SGML	Standard Generalized Markup Language
SPF	Shortest Path First
.tar	Tape ARchive (file name extension)
.tar.Z	Compressed Tape ARchived file (file name extension)
TA	Terminal Adapter
TCP/IP	Transmission Control Protocol/Internet Protocol
TD	Transmit Data
TIA	Telecommunications Industry Association
TSU	T1 Service Unit (*Adtran*)
T-1	Carrier bandwidth of 1.544 Mbps (2.048 Mbps in Europe)
UCSC	University of California Santa Cruz
UPS	Uninterruptible Power Supply
URL	Uniform Resource Locator
UTP	Unshielded Twisted-Pair
UU	Uuencode/Uudecode
WWW	World-Wide Web
.z	Packed file (file name extension)
.Z	Compressed file (file name extension)
.ZIP	Compressed File (file name extension)

REFERENCES

Abraham, R., Russell, W., and Jas, F., *The Web Empowerment Book*, Springer-Verlag Publishers, Santa Clara California, 1994.

Adtran Inc., "TSU User's Manual," Huntsville Alabama, March 1994.

Alverez, Luis M., MicroAge Director of Support Services, Interview, Monterey California, 2 June 1995.

American National Standards Institute (ANSI)/Institute of Electrical and Electronics Engineers (IEEE), *National Electrical Safety Code (NESC) Handbook*, 1993.

Apple Computer, Inc., WWW home page, Cupertino California, 1995. Available at *http://www.apple.com/*.

Atkinson, Marti, LAMBAY WWW Home Page, Santa Cruz, California, 1995. Available at: *http://sapphire.cse.ucsc.edu:80/mb/index.html*.

Baer, Paul, "BARRNet Pricing Proposal," electronic-mail correspondence to I^{3}LA net design team, 12 September 1994.

Beckley, Jeff, *Eudora by QUALCOM for Windows*, Install file, Qualcom Inc., San Diego California, October 1994.

Bellamy, Jim, "Monterey BayNet Frame Relay work request input matrix", Pacific Bell, Fresno California, April 6 1995.

Bigelow, Randall, J., "Monterey High Walkthru After Action Report," electronic-mail correspondence to I^{3}LA net design team, 1 November 1994.

Born, Roger L., "The Monterey Initiative for Information Infrastructure and Linking Applications," *American Society of Information Science Bulletin*, vol. 21 no. 4, April-May 1995.

Brutzman, Don, "Networked Ocean Science Research and Education, Monterey Bay California," *Internet Society INET '95*, Honolulu, Hawaii, 26-30 June 1995. Available at *http://inet.nttam.com/HMP/PAPER/039/html/paper.html* and *ftp://taurus.cs.nps.navy.mil/pub/i3la/i3laisoc.html*.

Brutzman, Don, editor, *Initiative for Information Infrastructure & Linkage Applications (I^3LA) Regional Network Design Tiger Team White Paper*, 25 May 1994. Available at *ftp://taurus.cs.nps.navy.mil/pub/i3la/i3la_net.txt* and in *PostScript* format at *ftp://taurus.cs.nps.navy.mil/pub/i3la/i3la_net.ps.*

California Department of Education (CDE), *Building the Future: K-12 Network Technology Planning Guide*, Sacramento, California, 1994. Available at 1-800-995-4099.

Case, J., Fedor, M., Schoffstall, M. and Davin, J., *A Simple Network Management Protocol (SNMP)*, Request for Comments 1157, Internet Engineering Task Force (IETF), May 1990. Available at *http://ds.internic.net/rfc/rfc1157.txt.*

Case, J., McCloghrie, K., Rose, M., and Waldbusser, S., *Introduction to Version 2 of the Internet-standard Network Management Framework*, Request for Comments 1441, Internet Engineering Task Force (IETF), April 1993. Available at *http://ds.internic.net/rfc/rfc1441.txt.*

Chen, K., Ho, K. and Saksena, V., "Analysis and Design of a Highly Reliable Transport Architecture for ISDN Frame Relay Networks," *IEEE Journal on Selected Areas in Communications*, vol. 7 no. 8 pp. 1231, October 1989.

Cisco Systems Inc., WWW Home Page, San Jose, California, 1995. Available at *http://www.cisco.com.*

Cisco Systems Inc., *UniverCD*, vol. 2 no. 4, Cisco Systems Knowledge Products, San Jose, California, 1995.

Cooper, A. and Postel, J., *The US Domain*, Request for Comments 1480, Internet Engineering Task Force (IETF), June 1993. Available at *http://ds.internic.net/rfc/rfc1480.txt.*

Cogger, Dick et al., *NEWS from the CU-SeeMe Developers*, README file, The CU-SeeMe Development Team, Cornell University, 16 January 1995. Available at *http://cu-seeme.cornell.edu/pub/CU-SeeMe/README.First.1-16-95.txt.*

Cradler, John and Bridgforth, Elizabeth, *1993-94 State Funding for Technology*, Far West Laboratory, San Francisco California, 29 September 1994.

Crocker, D., *"To Be 'On' the Internet,"* Request for Comments 1775, Internet Engineering Task Force (IETF), March 1995. Available at *http://ds.internic.net/rfc/rfc1775.txt.*

Davis, Helen and Bigelow, Randall, "On-Ramp to the Super Highway," training session, Naval Postgraduate School, Monterey California, 28 November 1994.

December, John and Randall, Neil, *The World Wide Web Unleashed,* 2nd ed., SamsNet Publishing, Indianapolis Indiana, 1995.

Dijkstra, E., "A Note on Two Problems in Connection with Graphs," *Numerical Mathematics,* October 1959.

Emswiler, Tracey, *Using the Multicast Backbone (MBone) for Distance Learning: A Case Study*, Master's Thesis, Naval Postgraduate School, Monterey California, September 1995.

Engst, Adam, *The Internet Starter Kit for the Macintosh*, Hayden Books, New York, 1994.

Garcia-Luna, J.J., "ATM As An Enabling Technology for Tele-education, Telescience, and Electronic Libraries Linking the Silicon Valley, Santa Cruz, and the Monterey Peninsula," CalREN grant proposal, University of California Santa Cruz, Santa Cruz California, 1994. Available at *http://www.pacbell.com/cgi-bin/textit?/SuperHi/CalREN/Projects/atmnorth-7.html.*

Gargano, J. and Wasley, D., *K-12 Internetworking Guidelines,* Request for Comments 1709, Internet Engineering Task Force (IETF), December 1994. Available at *http://ds.internic.net/rfc/rfc1709.txt.*

Gerich, E., *Guidelines for Management of IP Address Space,* Request for Comments 1466, Internet Engineering Task Force (IETF), May 1993. Available at *http://ds.internic.net/rfc/rfc1466.txt.*

Gwinn, Bob, Main Street School Instructor, correspondence to LT John Bigelow, Soledad California, 4 December 1994.

Herbst, Mike, "Access The Internet," information guide, Monterey County Office of Education, Salinas California, 17 March 1995.

Herbst, Mike, "Up and Running," electronic-mail correspondence to I^3LA net design team, 26 March 1995.

Herbst, Mike, "Video Conferencing," electronic-mail correspondence to I^3LA net design team, 12 May 1995.

Hronicek, Rick, "CalREN Summary of Target Data Communication Services," California Research and Education Network (CalREN), San Ramon California, 30 June 1993.

Hudson, Rich et al., Monterey Bay Technology Education Center (MBTEC), interview with MBTEC trainers, Seaside California, 7 September 1994.

Hughes, Kevin, "Entering the World-Wide Web: A Guide to Cyberspace," Enterprise Integration Technologies, Palo Alto California, May 1994. Available at *http://www.eit.com/web/www.guide/*.

International Business Machines Corporation (IBM), "IBM's New OS/2 Warp Opens Worlds of Computing to Users," IBM Press Release, New York, 11 October 1994.

Institute of Electrical and Electronics Engineers (IEEE) Computer Society, *IEEE Standard 802: Overview and Architecture*, October 1990. Originally known as *IEEE Standard 802.1A*. Describes Ethernet protocol.

Institute of Electrical and Electronics Engineers (IEEE) Computer Society, *Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications,* American National Standard ANSI/IEEE Std. 802.3, 1990.

Joseph, Linda C., *World Link An Internet Guide for Educators, Parents and Students,* Greyden Press, Coloumbus Ohio, 1995.

Krol, Ed, *The Whole Internet: User's Guide and Catalog*, O'Reilly and Associates Inc., Sebastapol California, 1993.

Lapp, Steven A., "MAC eudora- Setting up more than 1 user," electronic-mail correspondence to comp.mail.misc, 14 February 1995.

Long, Larry and Long, Nancy, *Computers,* 3rd ed., Prentice-Hall, Englewood Cliffs New Jersey, 1993.

Lloyd Internetworking, WWW home page, Cameron Park California, 1995. Available at *http://www.lloyd.com*.

Lloyd, Brian, "Network Design," electronic-mail correspondence to I^{3}LA net design team, 15 September 1994.

Lynch, Daniel C. and Rose, Marshall T., editors, *The Internet System Handbook,* Addison-Wesley, Reading Massachusetts,1993.

Macedonia, Michael R. and Brutzman, Donald P., "MBone Provides Audio and Video Across the Internet," IEEE *COMPUTER*, vol. 27 no. 4 pp. 30-36, April 1994. PostScript, text, and hypertext versions of this article are available as:
ftp://taurus.cs.nps.navy.mil/pub/i3la/mbone.ps.
ftp://taurus.cs.nps.navy.mil/pub/i3la/mbone.txt.
ftp://taurus.cs.nps.navy.mil/pub/i3la/mbone.html.

Malkin, G., *The Tao of IETF - A Guide for New Attendees of the Internet Engineering Task Force*, Request for Comments 1718, Internet Engineering Task Force (IETF), November 1994. Available at *http://ds.internic.net/rfc/rfc*1718.*txt*.

Manning, B., and Perkins, D., *Ways to Define User Expectations,* Request for Comments 1746, Internet Engineering Task Force (IETF), December 1994. Available at *http://ds.internic.net/rfc/rfc*1746.*txt*.

Matray, Kam, "Destination Tomorrow: Making Connections for the Ultimate Field Ttrip...," CalREN grant proposal, Monterey Peninsula Unified School District (MPUSD), Monterey California, 14 Mar 1994. Available at *http://www.pacbell.com/cgi-bin/textit?/ SuperHi/CalREN/Projects/educatio-9.html.*

Microsoft Corporation, WWW home page, Redmond Washington, 1995. Available at *http://www.microsoft.com.*

Mogel, J. and Postel, J., *Internet Standard Subnetting Procedure,* Request for Comments 950, Internet Engineering Task Force (IETF), August 1985. Available at *http://ds.internic.net/rfc/rfc*950.*txt*.

Moy, J., *OSPF Version 2*, Request for Comments 1583, Internet Engineering Task Force (IETF), March 1994. Available at *http://ds.internic.net/rfc/rfc1583.txt.*

National Center for Supercomputing Applications (NCSA), *NCSA Mosaic,* University of Illinois (UI), Urbana-Champaign, Illinois, 1994.

National Research Council (NRC), NRENAISSANCE Committee, *Realizing the Informaiton Future: The Internet and Beyond,* National Academy Press, Washington DC, 1994.

Netscape Communications Corporation (NCC), *Netscape Navigator v1.1N,* Mountain View California, 1995. Available at *http://home.netscape.com/.*

Onvural, Raif O., *Asynchronous Transfer Mode Networks: Performance Issues,* Artech House, Norwood Massachusetts, 1994.

Pacific Bell, WWW home page, San Francisco California, 1995. Available at: *http://www.pacbell.com*.

Pool, Greg, Monterey Academy of Ocanographic Science Instructor, Interview, Seaside California, 24 May 1995.

Postel, J., *Domain Name System Structure and Delegation,* Request for Comments 1591, Internet Engineering Task Force (IETF), March 1994. Available at *http://ds.internic.net/rfc/rfc1591.txt.*

Quality Education Data (QED) Inc., Student to computer ratios and state ranking, Peterson's Guides, Inc., Denver Colorado, 1994.

Rekhter, Y., et al., *Address Allocation for Private Internets,* Request for Comments 1597, Internet Engineering Task Force (IETF), March 1994. Available at *http://ds.internic.net/rfc/rfc1597.txt.*

RFC library, Internet Engineering Task Force (IETF). Available at *http://ds.internic.net/rfc/.*

Rosen, Eric C. and Wittenbrink, Craig M., Real-time Environmental Information Network & Analysis System (REINAS) WWW home page, Santa Cruz California, 1995. Available at *http://csl.cse.ucsc.edu/reinas.html.*

Sanders, John, "Virtual Night," training session, Naval Postgraduate School, Monterey California, 3 February 1995.

Sellers, J., *Internet School Networking (ISN) Charter*, isn-charter home page, Internet Engineering Task Force (IETF), May 1995. Available at *http://www.ietf.cnri.reston.va.us/html.charters/isn-charter.html.*

Sellers, J., *FYI on Questions and Answers: Answers to Commonly Asked ``Primary and Secondary School Internet User" Questions,* Request for Comments 1578, Internet Engineering Task Force (IETF), February 1994. Available at *http://ds.internic.net/rfc/rfc1578.txt.*

Sklower, K., Lloyd, B., McGregor, G. and Carr, D., *The PPP Multilink Protocol (MP),* Request for Comments 1717, Internet Engineering Task Force (IETF), November 1994. Available at *http://ds.internic.net/rfc/rfc1717.txt.*

Stallings, William, *Data and Computer Communications,* Macmillan Publishing, New York, NY, 1994.

Sprague, Ralph H. and McNurlin, Barbara C., *Information Systems Management in Practice,* 3rd ed., Prentice-Hall, Englewood Cliffs New Jersey, 1993.

Tattam, Peter R., "Trumpet Winsock Version 2.0," Trumpet Software International Pty. Ltd., Hobart Tasmania, Australia, 1994.

Taylor, Chris, "Status of LATA 1 & 8 CSUnet Connections," electronic-mail correspondence to I^3LA net design team, 29 Mar 95.

Trepanier, Dennis, "Wide-Area Network (WAN) Management: A Case Study," Master's Thesis, Naval Postgraduate School, Monterey California, September 1995.

Trepanier, Dennis, Buddenberg, Rex et al., *The Initiative for Information Infrastructure and Linkage Applications (I^3LA) Network: Physical Configuration Team Project*, Naval Postgraduate School, Monterey California, April 1995.

Whitten, Jeffery L., *Systems Analysis and Design Methods,* second edition., Irwin Press, Burr Ridge Illinois, 1989.

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